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Teamwork Online: The Effects of Computer Conferencing on Perceived Confusion, Satisfaction, and Postdiscussion Accuracy

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This study investigated the impact of computer-mediated communication on teamwork by examining 40 4-person teams working in either face-to-face or computer conferencing environments. Results were consistent with the belief that computer-mediated teams have trouble maintaining mutual knowledge. Compared with their face-to-face counterparts, computer-mediated teams viewed their discussions as more confusing and less satisfying, spent more time devising decisions, and felt less content with their outcomes. Discussion time mediated the relationship between the communication medium and outcome satisfaction. Confusion and outcome dissatisfaction predicted inaccuracies when members independently recorded team decisions; accordingly, the electronic communication medium reduced decision recording accuracy. By clarifying several shortcomings associated with computer conferencing, these results can be used to inform choices when selecting and developing effective team communication media.

Owing to increasingly rapid technological advances, computer-supported collaboration has become commonplace. The irresistible benefits of online communication have led to the widespread adoption of electronic communication tools throughout the world of work. Teams that collaborate via e-mail enjoy conveniences that free them from time and space restrictions: Members can meet when and where they want. Using computers as a collaboration medium can also increase the amount of information available to a group and amplify the speed and power with which team members acquire, process, and share their individual and collective efforts (McGrath & Hollingshead, 1994). Additionally, some research has shown computers to be a more egalitarian medium than face-to-face (FTF) communication (Bordia, 1997), with computer-mediated (CM) teams participating more evenly than do their FTF counterparts (Daly, 1993; Dubrovsky, Kiesler, & Sethna, 1991; Hiltz, Johnson, & Turoff, 1986; Kiesler, Siegel, & McGuire, 1984; Kiesler & Sproull, 1992; McGuire, Kiesler, & Siegel, 1987; Straus, 1996; Weisband, 1992).

Naturally, any given technological system can be expected to both benefit and hinder aspects of group process and performance (McGrath & Hollingshead, 1994). To this end, a number of obstacles accompany the advantages of computer conferencing. For instance, CM team members often lack awareness of the social context in which they are operating (Bordia, 1997). Cramton (2001) proposed that the failure to maintain mutual knowledge is a fundamental, overarching problem created by text-based, online communication channels. Mutual knowledge occurs when team members possess not only the same information but also an awareness that they share the knowledge. According to Krauss and Fussell (1990), it is achieved through several mechanisms, including direct

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knowledge (information gained via firsthand experience with individuals) and interactional dynamics (information acquired via collaborative discussions).

CM groups have trouble establishing mutual knowledge because they lack direct knowledge, which is gained through shared experiences in particular settings and firsthand observations of teammates' habits, situations, and environments (Cramton, 2001; Krauss & Fussell, 1990). Although CM teams can theoretically develop mutual knowledge through interactional dynamics, in practice they do not do so effectively, as indicated by research demonstrating that electronic communication adversely affects communication thoroughness (Jarvenpaa, Rao, & Huber, 1988; Smith & Vanecek, 1988, 1990). It has been suggested that interactional dynamics suffer during CM collaboration because give-and-take is hindered by the concentrated effort required to type and relay information that is easily transmitted via nonverbal and paraverbal nuances (e.g., gestures and vocal intonations) during FTF collaboration (Cramton, 2001). Online collaborators may attempt to communicate such nuances via a variety of techniques, such as complex syntax and redundancy; however, these techniques are generally regarded as low-quality, time-consuming substitutes for paraverbal and nonverbal cues (McGrath & Hollingshead, 1994).

Thus, establishing and maintaining mutual knowledge during electronic collaboration is labor intensive. CM teammates wishing to achieve common ground must verbalize much more information than those working FTF (Hightower & Sayeed, 1995). This viewpoint complements the social psychological perspective of Kiesler, Sproull, and colleagues, who have argued that computer conferencing affects teamwork by depersonalizing the interaction process and removing feedback such as nonverbal and paraverbal cues (Kiesler et al., 1984; Kiesler & Sproull, 1992; McGrath & Hollingshead, 1994). Consequently, an individual tends to lose "mental sight" of his or her teammates. That is, the team member loses a very particularized kind of mental image of the audience—an image that people ordinarily have during FTF collaboration. At the same time, the individual loses access to cues that provide feedback to teammates regarding the impact of their behavior (McGrath & Hollingshead, 1994).

The mutual knowledge problem may result in a variety of difficulties. Following an analysis of 13 six-member virtual teams, Cramton (2001) concluded that a lack of mutual knowledge disrupted the collaborative process considerably. CM team members (a) failed to communicate and retain contextual information; (b) unevenly distributed information that should have gone to the whole team simultaneously; (c) had trouble communicating and understanding the salience of information, such as a question or a request; (d) differed in the speed with which they were willing or able to access information; and (e) had trouble interpreting the meaning of silence.

Although it is believed that collaborative efforts suffer when online teams fail to develop mutual knowledge, there remain a variety of unanswered questions concerning the precise manner in which computer conferencing and its mutual knowledge deficits damage communication and alter team process and outcome variables. Accordingly, the purpose of the present study was to elucidate some of the shortcomings of electronic collaboration. After investigating the effects of computer conferencing on four specific variables (perceived discussion confusion, process satisfaction, outcome satisfaction, and decision recording accuracy), we examined the relationships among communication medium, team discussion time, and outcome satisfaction. We also tested whether confusion concerning the team discussion and dissatisfaction with the collaborative outcome predicted the extent to which people recorded their team decisions inaccurately. In general, our hypotheses and expectations were based on the contention that CM teams tend to suffer from a lack of mutual knowledge.

Perceived Discussion Confusion

Because the establishment of mutual knowledge increases the likelihood that communication will be understood (Clark, 1996; Clark & Carlson, 1982; Clark & Marshall, 1981; Cramton, 2001; Fussell & Krauss, 1992; Krauss & Fussell, 1990) and CM teams have trouble maintaining common ground, it is reasonable to expect that CM teams' mutual knowledge deficiencies will breed confusion. Because typing is usually more difficult than speaking, some CM discussion ideas remain less developed than those expressed orally; thus, a group member's true or intended meaning may be unclear to online teammates (Valacich & Schwenk, 1995). After examining 1,649 pieces of e-mail generated by 13 intact teams, Cramton (2001) concluded that communication across distance and via technology is an extraordinarily leaky process. "People worked from different information far more often than they realized. . . . Confusion and conflict was promulgated . . . by different interpretations of the same information" (p. 364).

The literature suggests that CM teams are indeed susceptible to communication and coordination difficulties, especially when their work requires a great deal of interdependence (Dennis, Hilmer, & Taylor, 1997; Straus & McGrath, 1994; Thompson & Coovert, 2002). Coordination challenges and subsequent discussion confusion may stem from a variety of specific problems, including the failure to properly attend to teammates' text-based, online contributions (Thompson & Probber, 2001) that may arise from virtual team members' ability to contribute to a discussion all at once as well as the chaotic sequencing of messages and information overload that result (McGrath & Hollingshead, 1994); a lack of informational feedback (Adrianson & Hjelmquist, 1991; Kiesler et al., 1984; Kiesler & Sproull, 1992); or a poor fit between the information richness requirements of a task and the information richness potential of the communication medium (Hollingshead, McGrath, & O'Connor, 1993).

A study by Probber and Foster (2000) supported the contention that computer conferencing tends to result in confusion. These authors investigated discussion comprehension by examining the perceptions of intact teams working on a structured CM exercise. These established teams had a history of working with one another, yet they were unaccustomed to computer conferencing together. They were asked to rate the coherence of their team's communication both before and directly after their online teamwork. Results suggested that the computer conferencing exercise adversely affected perceptions of team communication quality. To date, only one study has directly compared FTF and CM team discussion comprehension. Straus and McGrath (1994) administered O'Reilly and Roberts's (1976) scale of communication accuracy and openness to teams working in either an FTF or a CM environment. Results indicated that CM communication hindered members' ability to follow their team discussions. This line of inquiry warrants verification and a further identification of the boundary conditions surrounding the phenomenon. We therefore propose the following replication, using an alternative sample, task, and scale:

> *Hypothesis 1:* Compared with their FTF counterparts, people who engage in computer conferences will perceive their team discussions as more confusing.

Process and Outcome Satisfaction

Decrements in satisfaction are expected during CM communication because of the mutual knowledge problem. Mutual knowledge deficits in the teams examined by Cramton (2001) purportedly "caused serious problems in communication and relationships" (p. 364). It is reasonable to expect that these kinds of troubles adversely affect team members' feelings and attitudes concerning their collaboration. Notably, the transactional perspective stemming from the work of Hesse and colleagues (described in McGrath & Hollingshead, 1994) also suggests that computer mediation can adversely affect satisfaction by disrupting conversation sequencing.

Indeed, research has shown that newly formed FTF teams tend to be more satisfied than their CM counterparts (Adrianson & Hjelmquist, 1991; Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Carey & Kacmar, 1997; Chidambaram, 1996; Foster & Coovert, 1997; Hollingshead et al., 1993; McLeod, 1992; Straus, 1996; Straus & McGrath, 1994). In his comprehensive review of the research comparing FTF and CM collaboration, Bordia (1997) touched on satisfaction by proposing that CM communication can alter team members' evaluations of their communication partners and media. More recently, a meta-analysis by Baltes et al. (2002) concluded that CM communication decreases member satisfaction.

Although the satisfaction finding is fairly consistent, it lacks specificity (Olaniran, 1996). Indeed, it is not entirely clear *what* CM teams are less satisfied with. Ambiguity occurs because the team satisfaction questionnaires under investigation have tended to include a wide variety of items, such as satisfaction with the discussion, the process, the communication medium, and other members of the group. For example, the member satisfaction construct examined in the Baltes et al. (2002) meta-analysis included scales that both alluded to satisfaction with the group outcome and addressed the discussion process. Olaniran (1996), who urged CM team researchers to abandon the vague "team satisfaction" construct and report specific types of satisfaction instead, has offered the distinction between process and outcome satisfaction. Process satisfaction refers to contentment with the interactions that occur while team members are devising decisions. Outcome satisfaction encompasses approval of the final team decision.

A few cross-media studies have investigated process satisfaction specifically. Although a small number suggested that electronic communication did not affect (Jarvenpaa et al., 1988) or even increased (Valacich & Schwenk, 1995) process satisfaction, most revealed trends indicating that FTF teams generally felt more satisfied with the team process than did their CM counterparts (Gallupe & McKeen, 1990; Huang, Wei, & Tan, 1999;[1] Ocker & Yaverbaum, 1999; Straus, 1996; Warkentin, Sayeed, & Hightower, 1997). The following replication is therefore expected:

> *Hypothesis 2a:* Compared with their FTF counterparts, people who engage in computer conferences will feel less satisfied with their collaborative processes.

With regard to outcome satisfaction, some authors have concluded that there is little or no reason to expect differences between FTF and CM groups (Ocker & Yaverbaum, 1999) because research has generally indicated that FTF and CM teams do not significantly differ in terms of their overall contentment with the final team product (Benbunan-Fich & Hiltz, 1999; Huang et al., 1999 [see footnote 1]; Ocker & Yaverbaum, 1999; Valacich & Schwenk, 1995). In light of measurement problems and the inability to prove the null hypothesis, the potential effect of CM communication on outcome satisfaction warrants further consideration. Prior research has assessed outcome satisfaction via questionnaires that asked members to rate their reactions to items such as "How satisfied or dissatisfied are you with the quality of your team's solution?" Responses to this type of question are ambiguous when generated by members who report team solutions that do not agree with the solution provided by teammates (a common problem during CM collaboration, as explained later). When responding to such an item, it is impossible to determine whether the discrepant member is rating satisfaction with his or her reported solution or satisfaction with the solution produced by the majority. This problem can be avoided by listing the majority solution and having members rate that solution directly. As discussed next, CM teams are expected to express relatively low outcome satisfaction when such a measurement technique is used.

Research indicates that CM communication sometimes improves team performance, yet it often has no effect, and it occasionally worsens the results produced by teams (e.g., Adrianson & Hjelmquist, 1991; Archer, 1990; Gallupe, Bastianutti, & Cooper, 1991; Gallupe et al., 1992; Hollingshead, 1996; Hollingshead et al., 1993; McLeod, Baron, Marti, & Yoon, 1997; Straus, 1996). If outcome quality and outcome satisfaction were perfectly correlated, there would be no reason to predict a media effect on outcome satisfaction. These two constructs are distinct, however, and some have argued that outcome satisfaction should be viewed from a cost–benefit perspective. Time is a cost or an input that goes into teamwork, as suggested by McGrath and Hollinghead's (1994) assertion that "performance must be reckoned in terms of quantity, quality, and cost (of which speed, or cost in time, is a special case)" (p. 97). Teams should be less satisfied with a given outcome when it takes more time to achieve it (Purdy &

[1] The Huang et al. (1999) article reported that FTF teams expressed significantly more outcome satisfaction than CM teams when working on preference tasks and did not differ from CM teams in terms of process satisfaction when solving intellective tasks. However, Huang (W. Huang, personal communication, October 9, 2002) later indicated that this conclusion, which reflected a typographical error, is not correct. The article should have stated that FTF teams expressed significantly more process satisfaction than CM teams when working on intellective tasks and did not differ from CM teams in terms of outcome satisfaction when solving preference tasks.

Nye, 2000). In other words, after controlling for outcome quality, teams that work longer should feel less satisfied with their collaborative outcomes. This argument leads to the following prediction:

> *Hypothesis 2b:* Controlling for team solution quality, there will be a negative correlation between team discussion time and outcome satisfaction.

In accordance with the belief that establishing mutual knowledge during electronic collaboration is time and labor intensive, research has shown that dispersed teams tend to take longer than those who use FTF communication (Daly, 1993; Foster & Coovert, 1997; Gallupe & McKeen, 1990; Hollingshead, 1996; Kiesler & Sproull, 1992; McGuire et al., 1987; Straus, 1996; Weisband, 1992). Thus, the cost of teamwork (time) increases when moving from FTF to CM communication, yet the benefit (team performance) does not consistently improve. From a cost–benefit perspective, CM teams should therefore be less satisfied with their outcomes, and increased time requirements should explain the negative relationship between the use of CM communication and outcome satisfaction. This argument is strengthened by Purdy and Nye's (2000) study, which examined dyads working on a negotiation task via one of four media: computer chat, telephone, videoconferencing, or FTF. Following task completion, those using richer media expressed more outcome satisfaction on a one-item measure than those using sparser media. Moreover, time mediated the impact of media richness on outcome satisfaction (Purdy & Nye, 2000).

On the basis of the preceding arguments, we expected CM communication to have a negative effect on team members' contentment with their collaborative outcomes. After testing this hypothesis, we examined whether time mediated this relationship to determine whether Purdy and Nye's (2000) findings extend to groups, which are commonly defined as comprising three or more people (Baltes et al., 2002; Fjermestad & Hiltz, 2001).

> *Hypothesis 2c:* Compared with their FTF counterparts, people engaged in computer conferences will feel less satisfied with their collaborative outcomes.

> *Hypothesis 2d:* The relationship between media type and outcome satisfaction will be mediated by the time required to reach consensus.

Accuracy in Recording Team Decisions

By breeding confusion and dissatisfaction, a failure to maintain mutual knowledge during CM teamwork may adversely affect the accuracy of the outcome reported by team members. Following on a synthesis of experimental studies that compared FTF and CM communication, Bordia (1997) noted that group members who record the collective choice or decision make more errors when the teamwork occurs online than when it takes place in an FTF environment.

Although several experiments have supported this conclusion (Adrianson & Hjelmquist, 1991; Daly, 1993; Straus & McGrath, 1994), the antecedents of the problem have never been systematically examined. Nevertheless, speculation abounds, and the literature offers some convincing yet untested assertions concerning the variables that influence recording inaccuracy. Perhaps they occur because the mutual knowledge problem and its "consequences for cohesion and learning" (Cramton, 2001, p. 346) prevent teams from convincing members of the quality of the collective solution, leading a transcriber who is dissatisfied with the collaborative solution to independently "fix" the outcome prior to reporting it. Indeed, field research, though statistically insignificant, has suggested that anonymous CM communication may foster disagreement over final team choices (Hiltz, Turoff, & Johnson, 1989).

Having examined the content of the CM groups' verbal protocols, Straus and McGrath (1994) suggested that recording inaccuracies stemmed from CM team members' tendency to deliberately misrepresent their teams' decisions to promote their own divergent opinions. Alternatively, Daly (1993) attributed CM teams' recording inaccuracies to the tedium of error checking during CM communication, and Adrianson and Hjelmquist (1991) interpreted the errors as an indication that CM communicators are apt to develop confused or incorrect perceptions of the team's established decision—a potential consequence of the mutual knowledge problem supported by Arunachalam and Dilla's (1995) work, which indicated that CM collaborators tend to maintain relatively inaccurate perceptions of their teammates' preferences. The present study examined two explanations for decision recording inaccuracy. First, Hypothesis 3a is congruent with past research:

> *Hypothesis 3a:* Compared with their FTF counterparts, people engaged in computer conferences will record their decisions less accurately.

Next, two explanations for the decision recording accuracy problem were examined:

> *Hypothesis 3b:* Perceived confusion over the team discussion will contribute unique variance to the prediction of decision recording inaccuracy.

> *Hypothesis 3c:* Overall satisfaction with the team decision will contribute unique variance to the prediction of decision recording inaccuracy.

It was determined that Straus and McGrath's contention that CM members purposefully misrepresent team decisions to promote their own divergent opinions would receive tentative support if overall satisfaction with the team decision contributed unique variance. Additionally, if discussion confusion contributed unique variance, Adrianson and Hjelmquist's conjecture would be reinforced: Members of CM teams may tend to record their collaborative decisions incorrectly because they develop unclear perceptions of the teams' agreed-upon decisions, which may be inevitable when collaboration occurs in the absence of mutual knowledge.

Method

Participants

Forty 4-person teams of undergraduate students participated in the experiment.[2] The sample was 78% female, and a chi-square test of independence revealed that gender proportions did not significantly differ across the two experimental conditions, $\chi^2(1, N = 160) = 2.96$, $p = .09$. Approximately 87% of the sample was between the ages of 18 and 28, and chi-square analyses indicated that age-group proportions were also essentially equivalent across the two experimental conditions, $\chi^2(4, N = 160) = 1.41$, $p = .70$. Participation was voluntary and gave students the opportunity to earn extra credit for various university courses. Sign-up sheets instructed individuals to avoid volunteering to participate with friends and acquaintances.

Decision Task

Participants worked on Johnson and Johnson's (1994) desert survival problem, a complex task that is frequently used in small-group research and has generally been accepted as an analogue to problems encountered by temporary formal groups of individuals on the job (Bottger & Yetton, 1987; Burleson, Levine, & Samter, 1984; Rogelberg, Barnes-Farrell, & Lowe, 1992; Rogelberg & O'Connor, 1998; Straus, 1996). The task requires individuals to read a brief scenario describing students whose transportation has crashed and who find themselves stranded in the desert. Participants are asked to accept this plight as if it were their own, rank-order 12 items (e.g., compass, jacket, knife) according to their importance for survival, and then reanalyze the problem with team members. In the end, individual and team solutions are compared with an expert ranking, which is considered the correct answer to the problem. Comparisons between team and expert solutions gauge the extent to which teams are exercising their collective situational analysis and complex problem-solving competencies. It has been argued that the desert survival simulation gives participants the opportunity to practice their skills in both situational analysis and group decision making (Potter & Balthazard, 2002).

McGrath (1984) proposed that team tasks can be grouped into one of four categories or quadrants. Tasks in Quadrant I involve generating ideas or plans. This quadrant includes both generate–creativity activities (i.e., idea generation) and planning tasks. Quadrant II requires teams

[2] A power analysis was conducted using conventional FTF and computer conferencing team satisfaction data obtained from a previous study (Foster & Coovert, 1997). According to the recommended .05 and .80 alpha and power values, respectively, the power analysis yielded a suggested sample size of $n = 15$ teams per cell (Keppel, 1991). After considering the recommended sample size, we chose a conservative value of $n = 20$ teams per cell to ensure sensitive tests of the experimental hypotheses.

to choose a correct answer or a preferred solution and encompasses intellective tasks (solving problems with correct answers) and judgment tasks (solving problems without right answers). Tasks in Quadrant III involve negotiating conflicting views or interests. This quadrant includes negotiation/cognitive-conflict tasks (resolving conflicting viewpoints) and mixed-motive tasks (resolving conflicts of interest). Finally, Quadrant IV encompasses tasks involving "executing"—in competition against either an opponent or an external performance standard. This category includes contests and competitive tasks as well as performance and psychomotor tasks.

The task used in the present study was foremost a choosing problem that fell into Quadrant II of the group task circumplex described above. The desert survival problem has been dubbed an "interdependent intellective task" by researchers (e.g., Potter & Balthazard, 2002) because it requires teams to solve a problem with a correct answer. It can be argued that this task also includes characteristics of a judgment/decision-making problem (deciding issues without right answers), because unlike a math problem, for instance, it is impossible for a team member to prove the correctness of his or her argument. As Potter and Balthazard (2002) pointed out, the interdependency, which entails persuasion so that teammates can reach consensus, is one characteristic of a judgment/decision-making task. Finally, the desert survival problem contains features of a negotiation/cognitive-conflict task because it often requires teammates to resolve conflicting viewpoints regarding the appropriate ranking of items (e.g., ordering the map 1st vs. 12th); characteristics of the desert environment (e.g., arguing that the desert gets cold at night vs. maintaining that it always stays hot); and survival strategies (e.g., remaining at the crash site to increase the chances of being rescued vs. attempting to walk back to civilization).

Design and Procedure

Two experimental conditions corresponding to two communication media types (FTF and CM) were compared. Twenty 4-person teams participated in each condition. A small, private laboratory was used to collect data. The lab included several computers and a conference table. Participants' activities were divided into three unique phases: prediscussion, team discussion, and postdiscussion activities.

Prediscussion activities. When a 4-person team arrived at the lab, each member was randomly assigned an alias: J, K, L, or M. Within both conditions, team members were then escorted to computers. Dividers visually isolated each computer.

Participants in the FTF condition began with 30 min of filler activity to equalize experimental time in the conditions. These individuals were asked to read an article describing Internet job search technology. After participants read their articles, they completed a practice Internet job search task while the experimenter provided detailed, step-by-step instructions. FTF participants were then given time to independently practice using this new tool. During this activity, participants were able to see and hear the experimenter, but dividers prevented them from seeing one another. This filler activity was included to prevent differential fatigue levels across the two experimental conditions. In other words, the Internet job search training session was intended to equate FTF teams' time and energy requirements with those experienced by CM teams.

Participants in the CM condition began the session with 20 min of filler time. These individuals were asked to read an Internet job search article, and an abbreviated version of the Internet job search demonstration was provided.[3] Next, they were trained to use electronic mailing list/computer-conferencing software called the WebCT Bulletin Board. The standardized software training session was administered by an experimenter, it lasted approximately 10 min, and it allowed members the opportunity to independently practice using the communication software.

[3] This 20-min filler activity was included to equate traditional CM teams' time and energy requirements with those experienced by teams participating in two additional experimental conditions, which were examined for a different study (see Foster, 1999). Such time and energy equalization was necessary because data gathered from the CM teams in the current experiment were later compared with data gathered from the two additional conditions included in a different experiment.

After the Internet job search and WebCT Bulletin Board training sessions were completed by FTF and CM teams, respectively, hard copies of the task description, instructions, and ranking worksheets were provided to individuals participating in both experimental conditions. Ranking worksheets included the list of 12 desert items, which appeared alongside columns labeled “individual ranking” and “team ranking.”

After reviewing these materials, participants were asked to complete a computer-based pretask questionnaire, designed to gather self-rated typing speed, computer proficiency, and desert survival expertise levels. This questionnaire, which appeared on the monitor as soon as participants were seated at the computers, was closed upon completion. A computer-based desert survival ranking form, which was formatted so that it mirrored the ranking worksheet, was immediately made available in its place.

Next, individual ranking instructions were reviewed, and participants were given 10 min to devise their individual solutions, record their rankings on the worksheet, and enter the solutions into the computer. While devising their individual solutions, participants were allowed to take notes as they saw fit. The computer-based solution entry form was closed at the end of the 10-min period after members finished recording their individual rankings both on paper and in the computer.

Team discussion activities. After all prediscussion activities were completed, participants in the FTF condition moved to a small conference table. Members of CM teams remained at their computers, and dividers continued to separate them from one another. Within both conditions, the team task instructions were then reviewed. Team members were directed to work together to devise one best ranking solution. They had access to their task descriptions, instructions, notes, and individual rankings and were allowed to refer to and write on these materials as they wished. Teams were given a maximum of 77 min to complete their task and write the team ranking into the appropriate column on their worksheets. This proved to be more than enough time. An experimenter told participants that the five teams with the best scores would enter a drawing for a cash prize to be awarded at the end of the study. Participants were informed that all members must enter the same final ranking in order for a team to qualify for the drawing.

FTF teams communicated by directly conversing with one another. Place cards on the table identified each individual as J, K, L, or M. CM teams used the WebCT Bulletin Board software to communicate with one another electronically. The technology was similar to “chat” software in terms of speed, but it required participants to open and close messages, similar to e-mail. A message’s title and the sender’s alias appeared on a shared screen as soon as an individual typed and sent a message. Members sent messages to the whole team simultaneously, and everyone was able to read messages posted by everyone else. In terms of Clark and Brennan’s (1991) communication media classification framework, the WebCT Bulletin Board allowed text-based CM communication occurring in the complete absence of visibility, audibility, simultaneity, and sequentiality. In other words, CM teammates could not see each other (visibility); hear each other (audibility); send and receive messages at once and simultaneously, such as when a person smiles during a teammate’s utterance (simultaneity); or ensure that turns would occur in sequence (sequentiality). The software enabled cotemporality (a member could receive a contribution at roughly the same time in which his or her teammate produced it), reviewability (a person could go back and review teammates’ messages after they occurred), and partial revisability (Clark and Brennan have noted that computer teleconferencing allows partial revisability; what a person types is revisable prior to a carriage return and unrevisable afterward).

Within both experimental conditions, once team members agreed on a solution, they wrote it in the appropriate column of their ranking worksheets. Participants were asked to notify the experimenter if the team could not reach consensus. (No teams did so, suggesting that everyone believed their teams had reached consensus.) FTF team members then returned to the computers used during their prediscussion activities, and members of CM teams remained at their workstations.

Postdiscussion activities. Following the team consensus, an experimenter opened an electronic team ranking form on the computer. The participants were instructed to individually and simultaneously enter the team’s ranking into the computer. An experimenter then collected all materials (task description, instructions, individual rankings, team ranking sheets, and scrap paper) and closed the electronic team ranking form.

Next, participants were given the first two pages of a three-page, paper-based, postexperimental questionnaire designed to gather personal and demographic information and perceptions regarding the team process, the team outcome, and experimental procedures. While they were filling this out, the experimenter privately reviewed the ranking worksheets to determine the team solution reported by the majority and wrote that solution on the final page of the questionnaire, which included two items that directly referred to the ranking written on the page. The experimenter distributed a copy of this final page to each of the team members while they were completing the first portion of the questionnaire.

After all materials were completed and gathered, team members were debriefed, informed of their individual and team solution scores, and dismissed. Participants were given approximately 20 min to complete their postdiscussion activities. Throughout the study, all time limits were based on pilot testing and previous work in this area (e.g., Adrianson & Hjelmquist, 1991; Foster & Coovert, 1997).

Measured Variables

Pretask self-assessments, manipulation checks, and demographic data. Participants were asked to provide several ability estimations. A 1 (*very slow*) to 5 (*very fast*) scale was used to measure self-rated typing speed, and a 1 (*novice*) to 5 (*expert*) scale was used to assess both computer and outdoor survival expertise. These items were administered via the pretask questionnaire. The posttask questionnaire assessed age, gender, and perceptions of teammates' authenticity. The latter item asked participants to use a 1 (*strongly disagree*) to 5 (*strongly agree*) scale to rate their reactions to the following statement: "I was working with other student participants." This item was administered to address the possibility that members of computer conferencing teams may have been inclined to believe that they were working with experimental confederates.

Individual prediscussion solution quality. An individual's prediscussion solution quality score was derived by computing the absolute difference between the prediscussion ranking and a predetermined criterion. The criterion was the correct solution published by Johnson and Johnson (1994). The absolute difference between the two rankings was subtracted from 100. This reverse-scaling procedure, which has been used in past research (Rogelberg & O'Connor, 1998), was conducted so that high scores reflected high-quality solutions.

Desert survival proficiency. Participants completed five multiple-choice desert survival test items via the pretask questionnaire. Each item (e.g., "Which of the following is the best survival strategy when stranded in the desert with limited amounts of water?") was accompanied by four multiple-choice responses (e.g., (a) Wear as little clothing as possible; (b) Shield yourself from the wind; (c) Conserve water by drinking as little as possible; (d) If food is available, eat as much as you can). Item content was drawn from a book designed to train military personnel for desert survival. For each participant, the number of test items answered correctly was added to the individual solution quality score to determine the desert survival proficiency score. Desert survival proficiency scores were used to compare the preexperimental knowledge levels of participants taking part in the two conditions.

Team solution quality. This measure was based on the ranking reported by the majority of the team members. Team solution quality scores were computed by determining the absolute difference between the majority ranking and the correct ranking, and then subtracting this index from 100. Again, we reversed this scale so that high scores reflected high-quality solutions.

Team discussion time. The total number of minutes that elapsed between the beginning and the end of the team discussion was measured.

Perceived discussion confusion. Three posttask questionnaire items ($\alpha = .78$) asked members to use a 1 (*strongly disagree*) to 5 (*strongly agree*) rating scale to indicate the degree to which they considered their team discussions confusing. An example item is "Sometimes it was hard to follow the discussion." Two of the three items were administered but not reported in a study conducted by Straus (1996). Responses to the three questions were averaged to create a single rating score for each individual. High scores represented great amounts of confusion.

Process satisfaction. Green and Taber's (1980) five-item Decision Scheme Satisfaction Scale was administered via the posttask questionnaire to assess the degree to which members felt satisfied with their team processes. Five-step semantic differential scales with anchors such as *satisfying* to *dissatisfying* followed the question "How would you describe your team's problem solving process?" Green and Taber reported a median coefficient alpha of .88 for this scale; we found an alpha of .91 and averaged responses to the five questions. As with Green and Taber's original questionnaire, high scores denoted high process satisfaction.

Outcome satisfaction. The team ranking reported by the majority of the members was hand-written alongside the desert survival items on the posttask questionnaire prior to its distribution. Two items ($\alpha = .93$) used 5-point scales to assess each participant's satisfaction with the quality of the solution provided. The first item asked team members to use a 1 (*very poor*) to 5 (*excellent*) scale to respond to the following request: "Please rate the quality of the ranking solution listed above." The second item used a 1 (*strongly disagree*) to 5 (*strongly agree*) scale to assess reactions to the following statement: "To what extent do you agree that the above ranking is a good solution?" Responses to the two items were averaged for each individual; higher scores denoted greater outcome satisfaction. This measure is arguably better than previous attempts to assess outcome satisfaction, which are problematic for the reasons discussed earlier.

Recording inaccuracy. Recording inaccuracy scores were devised by computing the absolute difference between the majority team ranking and the team ranking entered into the computer by each member. Higher scores reflected greater inaccuracy.

Results

Background Analyses

Table 1 provides a correlation matrix describing the relationships among perceived confusion, process satisfaction, and the other variables investigated. As shown in Table 2, baseline analyses indicated that participants across the two experimental conditions did not systematically differ in terms of relevant pretask variables: desert survival proficiency, self-rated outdoor survival expertise, computer expertise, and typing speed.

Table 3 verifies that visually isolated persons in the computer conferencing condition were not particularly inclined to incorrectly assume they were working with experimental confederates. Table 3 also provides two different types of intraclass correlation coefficient (ICC) to describe the appropriateness of aggregating the variables investigated in this study and analyzing them at the team level. ICC(1), which is

Table 1
Correlations Among Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	—											
2. Typing speed	−.09	—										
3. Computer expertise	−.12	.43**	—									
4. Outdoor survival expertise	−.01	.11	.35**	—								
5. Individual solution quality	−.04	.08	.08	.23**	—							
6. Desert survival proficiency	−.02	.07	.08	.23**	.99**	—						
7. Team solution quality	−.02	.21**	.10	.04	.30**	.30**	—					
8. Team discussion time	−.08	.08	.12	.09	−.03	−.02	.03	—				
9. Recording inaccuracy	−.04	.02	.04	−.03	−.17*	−.18*	.14	.16	—			
10. Perceived confusion	−.06	.00	.04	.08	.02	.04	.11	.59**	.23**	—		
11. Process satisfaction	.12	.03	.04	.05	−.06	−.07	−.11	−.47**	−.19*	−.60**	—	
12. Outcome satisfaction	.08	.03	−.15	.10	.00	.01	.00	−.20*	−.20*	−.24**	.50**	—

Note. $N = 160$. The above correlations resulted from individual-level analyses.
* $p < .05$ (two-tailed). ** $p < .01$ (two-tailed).

Table 2
Prediscussion Comparisons Between Face-to-Face and Computer-Mediated Participants

Variable	Face-to-face (n = 80)		Computer-mediated (n = 80)				
	M	SD	M	SD	t(158)	p	η^2
Desert survival proficiency	57.26	9.30	55.46	8.53	1.28	.204	.010
Self-rated outdoor survival expertise	2.24	0.98	2.31	0.98	−0.48	.629	.001
Self-rated computer expertise	2.70	0.92	2.89	0.78	−1.39	.166	.012
Self-rated typing speed	2.95	0.81	3.08	0.81	−0.98	.330	.006

based on the F test, shows the proportion of variance in each dependent measure that was explained by team membership. As indicated in Table 3, two of the variables—perceived discussion confusion and process satisfaction—produced statistically significant analyses of variance, supporting team-level analyses of these measures. An ICC(2) value higher than .70 demonstrated that between-team differences on the same two variables were reliable (Klein et al., 2000).

Perceived Discussion Confusion

Hypothesis 1 anticipated that members of computer conferencing teams would be more confused with the discussion than members of FTF teams. As shown in Table 3, CM teams were less inclined to believe that they understood their collaborative discussions. These data supported Hypothesis 1, thereby replicating previous research with a different sample, task, and measurement scale. Clearly, CM teams are susceptible to confusing communication problems.

Process and Outcome Satisfaction

Hypothesis 2a predicted that people engaged in computer conferences would feel relatively dissatisfied with their collaborative processes. The statistics presented in Table 3 support Hypothesis 2a and replicate previous findings: FTF

Table 3
Postdiscussion Comparisons Between Face-to-Face and Computer-Mediated Participants

Variable	ICC(1)	ICC(2)	Face-to-face			Computer-mediated						
			n	M	SD	n	M	SD	df [a]	t	p	η^2
Perceived teammate authenticity	.004	.015										
Individuals			80	4.40	0.72	80	4.26	0.74	158	1.19	.237	.009
Teams			20	4.40	0.39	20	4.26	0.34	38	1.19	.243	.036
Perceived discussion confusion[b]	.427[c]	.749										
Individuals			80	2.11	0.81	80	3.29	0.78	158	−9.38	< .001	.358
Teams			20	2.11	0.49	20	3.29	0.43	38	−8.11	< .001	.634
Process satisfaction[b]	.425[c]	.747										
Individuals			80	4.25	0.70	80	3.33	0.83	158	7.54	< .001	.264
Teams			20	4.25	0.52	20	3.33	0.47	38	5.81	< .001	.471
Outcome satisfaction[b]	.066	.220										
Individuals			80	4.23	0.63	80	3.83	1.00	133	3.02	.003	.055
Teams			20	4.23	0.35	20	3.83	0.53	38	2.83	.007	.174
Recording inaccuracy[b]	.023	.085										
Individuals			80	0.03	0.22	80	1.51	5.93	79	−2.24	.028	.031
Teams			20	0.03	0.11	20	1.51	2.96	33	−2.25	.030	.118

Note. ICC = intraclass correlation.
[a] The degrees of freedom were adjusted downward and a separate variances test was used when the two conditions failed to demonstrate homogeneity of variance. [b] The two conditions significantly differed in terms of this variable. [c] This ICC(1) produced a statistically significant analysis of variance, supporting team-level analyses of this measure.

teams felt significantly more satisfied with their collaborative processes than did their CM counterparts.

Hypotheses 2b through 2d addressed outcome satisfaction. The first of these three predictions anticipated a negative correlation between discussion time and outcome satisfaction, controlling for team solution quality. A significant relationship was found between time and outcome satisfaction with team solution quality extracted ($r = -.36$, $n = 40$, $p = .03$, two-tailed). Hypothesis 2b was therefore upheld.

It is well known that CM communication slows team decision-making processes, and this occurred within our sample. Teams engaged in computer conferences ($M = 63.00$, $SD = 7.25$) took longer than those relying on FTF communication ($M = 28.85$, $SD = 14.35$), and this difference was significant, $t(38) = -9.50$, $p < .01$, $\eta^2 = .704$. Despite the increased discussion time, CM team solution quality scores ($M = 56.10$, $SD = 12.59$) did not exceed FTF scores ($M = 55.10$, $SD = 10.89$) at a significant level, $t(38) = -0.27$, $p = .79$, $\eta^2 = .002$. Nonetheless, Hypothesis 2c predicted that people who engaged in computer conferencing would feel relatively dissatisfied with the quality of their team solutions. As shown in Table 3, CM team members felt less satisfied with their outcomes than did FTF members, thereby supporting Hypothesis 2c. An examination of the effect sizes reported in Table 3 indicates that the communication medium did not influence outcome satisfaction as much as it affected process satisfaction.

Hypothesis 2d was guided by a mediated model that considered discussion time the key process by which media differences influenced outcome satisfaction. As outlined by Baron and Kenny (1986), four conditions must be present to demonstrate full mediation. For the model tested in this study, all four conditions were met: (a) Media differences predicted outcome satisfaction ($r = -.42$, $n = 40$, $p = .01$, two-tailed); (b) media differences predicted discussion time ($r = .84$, $n = 40$, $p < .01$, two-tailed); (c) discussion time predicted outcome satisfaction ($r = -.36$, $n = 40$, $p = .02$, two-tailed); and (d) the effect of media differences on outcome satisfaction, controlling for discussion time, was not significantly different from zero ($r = -.23$, $n = 40$, $p = .16$, two-tailed). Hypothesis 2d was therefore supported.

Accuracy in Recording Team Decisions

The third set of hypotheses looked at recording errors. As expected, people engaged in computer conferences recorded their team decisions less accurately than did their FTF counterparts. The recording inaccuracy scores (i.e., the absolute difference between the majority team ranking and the team ranking entered into the computer by each member) supported Hypothesis 3a, as shown in Table 3. Only 1 person (1.25%) from the FTF condition made mistakes, generating a total of 2 recording errors; conversely, 14 people (17.5%) from the CM group miscoded a total of 53 items. As previously noted, speculation within the research literature suggests that dissatisfaction and/or confusion regarding team decisions cause recording inaccuracies. A multiple regression analysis revealed a value of $R^2_{\text{inaccuracy.confusion,satisfaction}} = .08$, which was statistically significant, $F(2, 157) = 6.47$, $p = .01$. Thus, a linear combination of discussion confusion and outcome satisfaction scores explained a small but statistically significant amount of the variance in recording inaccuracy. Hypotheses 3b and 3c anticipated that individuals' satisfaction with the team decision and their confusion over the team discussion would each contribute unique variance to the prediction of decision recording accuracy. The discussion confusion variable ($b_1 = .19$) contributed to the previously reported regression equation, $t(157) = 2.45$, $p = .02$, and the outcome satisfaction variable ($b_2 = -.16$) also provided a significant contribution, $t(157) = -1.98$, $p = .05$. In short, the results supporting Hypotheses 3b and 3c lent credence to both Adrianson and Hjelmquist's (1991) and Straus and McGrath's (1994) previously untested explanations for the recording errors that occurred during CM communication.

Discussion

This study highlighted and clarified some of the shortcomings of computer conferencing. The findings can be explained from the overarching perspective that the use of CM communication during teamwork creates a mutual knowledge problem, which is considered the mechanism underlying the media effects that occurred in this study. According to the mutual knowledge viewpoint, the use of CM communication leads to difficulty establishing and/or maintaining common ground. This problem results in more confusion (Hypothesis 1) and longer discussions as teammates work to develop mutual knowledge. Long, confusing discussions, among other things, decrease process satisfaction (Hypothesis 2a). The cost–benefit rationale would hold that time increases in the absence of performance increases reduce outcome satisfaction (Hypothesis 2b). The use of CM communication therefore adversely affects team members' contentment with their collective decisions (Hypothesis 2c), and this occurs because CM discussions are lengthy (Hypothesis 2d). In the end, team members who have struggled to maintain common ground are particularly inclined to record their decisions inaccurately (Hypothesis 3a), in part because the lack of mutual knowledge resulted in confusion about what was actually decided (Hypothesis 3b) and in part because of the dissatisfaction they felt regarding the collective product they have been asked to report (Hypothesis 3c).

This study supported previous findings and provided new information concerning the impact of CM communication on teamwork. We replicated the effects of CM communication on perceived discussion confusion and decision recording inaccuracy, and offered empirical support for two previously untested predictors of postdiscussion recording errors. Because the analyses addressing these inaccuracies were not designed to determine causal relationships, future research should use alternative methods (e.g., experimental manipulations) to determine whether outcome dissatisfaction and discussion confusion *cause* decision recording inaccuracies. This is a serious issue for dispersed work groups and teams, who often appoint a transcriber to transmit final team products and decisions to others (e.g., colleagues and supervisors) outside of the team.

As McGrath and Hollingshead (1994) pointed out, a full assessment of the impact of technology on teams needs to take user reactions into account. This research elucidated the effects of computer conferencing on satisfaction. Most prior research has investigated and reported a nebulous satisfaction construct, which includes satisfaction with the discussion, the process, the communication medium, and so forth. By narrowing and specifying the satisfactions of interest, the current initiative begins to clarify the manner in which CM communication affects team members' postdiscussion perceptions. The process satisfaction results presented in this study replicated prior research, and the outcome satisfaction findings were based on a new measurement approach and thus provided a unique contribution. Together, the results led to the conclusion that although CM communication adversely affects team outcome satisfaction, it has an even larger effect on team process satisfaction.

The data revealed a negative correlation between discussion time and outcome satisfaction, along with evidence that lengthy discussions were the key process by which media differences influenced outcome satisfaction. This result is consistent with Purdy and Nye's (2000) finding that time mediated the impact of media richness on outcome satisfaction among dyads working on a negotiation task. The cost–benefit argument seeks to explain why CM teams are less satisfied with outcomes that are no worse than those generated by their FTF counterparts. According to this viewpoint, the FTF and CM teams examined in the present study expressed different amounts of outcome satisfaction because they experienced different cost–benefit ratios. Compared with their FTF counterparts, CM teams sacrificed more time (cost), yet they did not generate better products (benefit), thereby producing a less favorable ratio. Although our findings were consistent with the assertion that cost–benefit comparisons account for cross-media differences in outcome satisfaction, we did not investigate the cost–benefit hypothesis directly; additional research would be informative. Furthermore, it is important to note that real-world CM teamwork is often accompanied by reductions in travel time and cost. In the future, it would be useful to determine whether these factors affect cost–benefit perceptions and outcome satisfaction.

In terms of solution quality, performance differences between the two conditions were neither expected nor found. Research has suggested that the effectiveness of CM teams, which is influenced by factors such as time pressure and anonymity, is not uniformly superior or inferior to the effectiveness of FTF teams. Meta-analytic findings have indicated that CM communication does not affect the performance of anonymous groups, such as those included in the present study, who do not experience a sense of time urgency (Baltes et al., 2002). According to the same meta-analysis, there is reason to expect that the external validity of the present study's team performance results is limited. CM communication can be expected to impair the performance of teams that are identifiable or working under time pressure (Baltes et al., 2002).

It is necessary to consider other boundary conditions as well. Particularly, the generalizability of the technology, the task, and the sample must be examined. First, the features of the software used during the current study may very well limit the settings to which the findings generalize. CM communication technologies that incorporate different degrees of visibility, audibility, cotemporality, simultaneity, sequentiality, reviewability, and revisability may have effects that were not seen owing to the features of the software chosen for our study. Because different kinds of technology influence different parts of the team process, various technologies should have different patterns of consequences (both positive and negative) depending on the team task (McGrath & Hollingshead, 1994). E-mail, electronic bulletin boards, and chat rooms are the technology-mediated environments to which the current results will most probably extend. The results do not necessarily generalize to mixed-media teams (e.g., those who are able to pick up the phone when the going gets rough). Future research should examine how secondary media alternatives affect team processes and outcomes during online collaboration.

Second, in light of the evidence that the effects of communication media on teamwork interact with task type, there is reason to believe that the results of this study may not generalize to all types of team tasks. Electronic communication media have a low potential for information richness. According to McGrath and Hollingshead (1994), such media provide a good information-richness fit for teams working on generating tasks (which have a low information-richness requirement), a marginal fit for those working on intellective tasks (which require mid-to-low information richness), and a poor fit for teams engaged in both judgment tasks (which have a mid-to-high information-richness requirement) and negotiation tasks (which require maximally rich information). Our teams completed an intellective activity that possessed some characteristics of judgment and negotiation tasks. It can therefore be assumed that the electronic medium provided a marginal-to-poor fit for the teams investigated in this study. Although the electronic communication medium had particular effects on the attitudes and behaviors of participants of this study, perhaps it would influence teams with better and poorer fitting assignments differently.

Third, our participants were students who had not worked together before this study. In addition to the usual cautions regarding the investigation of student participants (e.g., Will managers in organizations respond to the technology in a manner that is consistent with student behaviors and reactions?), we must consider the fact that the teams in this study had no history of working together. Rather, our participants assembled for a short period of time, and they existed to work on a single topic. They formed for only a single meeting, during which members communicated primarily in an each-to-all fashion. Some natural groups, such as project teams and temporary task forces, do exist only for a single meeting and work on only a single topic (McGrath & Hollingshead, 1994). The present results are seemingly most relevant for these types of teams. One must question whether the results of this study extend to teams who have a history of working together. As noted, electronic media are on the lean end of the information-richness potential continuum. Teams in the early stages of their development seem to require high levels of information richness to carry out member support functions and task performance strategies. The same teams can typically carry out their functions with less rich information exchanges as they mature (McGrath & Hollingshead, 1994). In short, mature teams may not experience the confusion and dissatisfaction that our teams encountered when communicating online. There is also reason to doubt whether some of the current findings apply to teams who have a future of working together. The effects of CM communication on decision recording inaccuracies may not generalize to team members who anticipate the need to collaborate in the future. The social consequences for misrepresenting the collective decision may be more serious for groups with a future, compared with temporary project teams and task forces. Such groups may therefore avoid the types of inaccuracies that stem from dissatisfaction with the collective decision.

Fourth and finally, it is important to question whether the effects in this study generalize to people who have experience collaborating together online. Research has shown that experience working together online can moderate the effects of CM collaboration (Hollingshead et al., 1993; Walther & Burgoon, 1992); therefore, it is unclear whether the current findings extend to teams who frequently rely on electronic media to communicate. It is entirely possible that people who commonly work with their teammates electronically will acquire distinct thoughts, feelings, strategies, and patterns of behaviors that are not fully consistent with those expressed by the electronic team members in this study, who were not used to working together online.

Project teams and task forces typically choose their communication media haphazardly, yet the present study suggests that this choice should not be taken lightly. Although there are many positive benefits associated with CM communication, not the least of which involves the elimination of the time and space requirements that accompany FTF teamwork, CM communication technology should be chosen cautiously. By clarifying the shortcomings of CM teamwork, this study can help today's workplace teams make informed decisions on when and whether to engage in text-based meetings online. Considering the discussion confusion perceptions associated with CM communication, workplace teams and task forces may wish to choose an FTF or video-mediated environment for teamwork requiring extensive coordination. Alternatively, teams that are inclined to use CM communication for highly complex and interdependent tasks should consider developing, testing, and implementing explicit strategies that promote clarity and comprehension among members who engage in CM communication. To this end, it would be interesting to examine whether such strategies also improve recording accuracy, process satisfaction, discussion times, and outcome satisfaction in a CM team setting.

> It is not only possible, but indeed very likely, that in the future, by combinations of current systems, and/or by introduction of radically new systems, advanced technological systems will be attained with features that overcome or offset some of the disadvantages and enhance some of the advantages found (in current systems). (McGrath & Hollingshead, 1994, p. 11)

By elucidating some of the shortcomings associated with CM collaboration, this study and others can help set an agenda for those building the computer-supported cooperative work technologies of the future. Such an approach can lead to increasingly effective CM teamwork in the days to come.

References

Adrianson, L., & Hjelmquist, E. (1991). Group processes in face-to-face and computer-mediated communication. *Behaviour & Information Technology, 10,* 281–296.

Archer, N. P. (1990). A comparison of computer conferences with face-to-face meetings for small group business decisions. *Behaviour & Information Technology, 9,* 307–317.

Arunachalam, V., & Dilla, W. N. (1995). Judgment accuracy and outcomes in negotiation: A causal modeling analysis of decision-aiding effects. *Organizational Behavior and Human Decision Processes, 61,* 289–304.

Baltes, B. B., Dickson, M. W., Sherman, M. P., Bauer, C. C., & LaGanke, J. S. (2002). Computer-mediated communication and group decision making: A meta-analysis. *Organizational Behavior and Human Decision Processes, 87,* 156–179.

Baron, R., & Kenny, D. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173–1182.

Benbunan-Fich, R., & Hiltz, S. R. (1999). Impacts of asynchronous learning networks on individual and group problem solving: A field experiment. *Group Decision and Negotiation, 8,* 409–426.

Bordia, P. (1997). Face-to-face versus computer-mediated communication: A synthesis of the experimental literature. *Journal of Business Communication, 34,* 99–120.

Bottger, P. C., & Yetton, P. W. (1987). Improving group performance by training in individual problem solving. *Journal of Applied Psychology, 72,* 651–657.

Burleson, B. R., Levine, B. J., & Samter, W. (1984). Decision-making procedure and decision quality. *Human Communication Research, 10,* 557–574.

Carey, J. M., & Kacmar, C. J. (1997). The impact of communication mode and task complexity on small group performance and member satisfaction. *Computers in Human Behavior, 13,* 23–49.

Chidambaram, L. (1996). Relational development in computer-supported groups. *MIS Quarterly, 20,* 143–165.

Clark, H. H. (1996). *Using language*. New York: Cambridge University Press.

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: American Psychological Association.

Clark, H. H., & Carlson, T. B. (1982). Speech acts and hearer's beliefs. In N. V. Smith (Ed.), *Mutual knowledge* (pp. 1–36). New York: Academic Press.

Clark, H. H., & Marshall, C. R. (1981). Definite reference and mutual knowledge. In A. Joshi, I. Sag, & B. Webber (Eds.), *Elements of discourse understanding* (pp. 10–63). New York: Cambridge University Press.

Cramton, C. D. (2001). The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science, 12,* 346–371.

Daly, B. L. (1993). The influence of face-to-face versus computer-mediated communication channels on collective induction. *Accounting, Management, and Information Technologies, 3,* 1–22.

Dennis, A. R., Hilmer, K. M., & Taylor, N. J. (1997). Information exchange and use in GSS and verbal group decision making: Effects of minority influence. *Journal of Management Information Systems, 14,* 61–88.

Dubrovsky, V. J., Kiesler, S., & Sethna, B. N. (1991). The equalization phenomenon: Status effects in computer-mediated and face-to-face decision-making groups. *Human Computer Interaction, 6,* 119–146.

Fjermestad, J., & Hiltz, S. R. (2001). Group support systems: A descriptive evaluation of case and field studies. *Journal of Management Information Systems, 17,* 115–159.

Foster, L. L. (1999). *Effects of computer-mediated communication and intelligent agent assistance on team decision making.* Unpublished doctoral dissertation, University of South Florida, Tampa.

Foster, L. L., & Coovert, M. D. (1997). The influences of communication media and decision-making technique on team decision outcomes: A critical assessment of the stepladder approach. *Proceedings of the CHI 97 Conference on Human Factors in Computing Systems,* 240–241.

Fussell, S. R., & Krauss, R. M. (1992). Coordination of knowledge in communication: Effects of speakers' assumptions about what others know. *Journal of Personality and Social Psychology, 62,* 378–391.

Gallupe, R. B., Bastianutti, L. M., & Cooper, W. H. (1991). Unblocking brainstorms. *Journal of Applied Psychology, 76,* 137–142.

Gallupe, R. B., Dennis, A. R., Cooper, W. H., Valacich, J. S., Nunamaker, J. J., & Bastianutti, L. (1992). Electronic brainstorming and group size. *Academy of Management Journal, 35,* 350–369.

Gallupe, R. B., & McKeen, J. D. (1990). Enhancing computer-mediated communication: An experimental investigation into the use of a group decision support system for face-to-face versus remote meetings. *Information & Management, 18,* 1–13.

Green, S. G., & Taber, T. D. (1980). The effects of three social decision schemes on decision group process. *Organizational Behavior and Human Performance, 25,* 97–106.

Hightower, R., & Sayeed, L. (1995). The impact of computer-mediated communication systems on biased group discussion. *Computers in Human Behavior, 11,* 33–44.

Hiltz, S. R., Johnson, K., & Turoff, M. (1986). Experiments in group decision making: Communication process and outcome in face-to-face versus computerized conferences. *Human Communication Research, 13,* 225–252.

Hiltz, S. R., Turoff, M., & Johnson, K. (1989). Experiments in group decision making: 3. Disinhibition, deindividuation, and group process in pen name and real name computer conferences. *Decision Support Systems, 5,* 217–232.

Hollingshead, A. B. (1996). The rank-order effect in group decision making. *Organizational Behavior and Human Decision Processes, 68,* 181–193.

Hollingshead, A. B., McGrath, J. E., & O'Connor, K. M. (1993). Group task performance and communication technology: A longitudinal study of computer-mediated versus face-to-face work groups. *Small Group Research, 24,* 307–333.

Huang, W., Wei, K., & Tan, B. C. Y (1999). Compensating effects of GSS on group performance. *Information & Management, 35,* 195–202.

Jarvenpaa, S. L., Rao, V. S., & Huber, G. P. (1988). Computer support for meetings of groups working on unstructured problems: A field experiment. *MIS Quarterly, 12,* 645–666.

Johnson, D. W., & Johnson, F. P. (1994). *Joining together: Group theory and group skills* (5th ed.). Boston: Allyn & Bacon.

Keppel, G. (1991). *Design and analysis: A researcher's handbook* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Kiesler, S., Siegel, J., & McGuire, T. W. (1984). Social psychological aspects of computer-mediated communication. *American Psychologist, 39,* 1123–1134.

Kiesler, S., & Sproull, L. (1992). Group decision making and communication technology. *Organizational Behavior and Human Decision Processes, 52,* 96–123.

Klein, K. J., Bliese, P. D., Kozlowski, S. W. J., Dansereau, F., Gavin, M. B., Griffin, M. A., et al. (2000). Multilevel analytic techniques: Commonalities, differences and continuing questions. In

K. J. Klein & S. W. J. Kozlowski (Eds.), *Multilevel theory, research, and methods in organizations: Foundations, extensions, and new directions* (pp. 512–553). San Francisco: Jossey-Bass.

Krauss, R. M., & Fussell, S. R. (1990). Mutual knowledge and communicative effectiveness. In J. R. Galegher, R. E. Kraut, & C. Egido (Eds.), *Intellectual teamwork: Social and technological foundations of cooperative work* (pp. 111–145). Hillsdale, NJ: Erlbaum.

McGrath, J. E. (1984). *Groups: Interaction and performance.* Englewood Cliffs, NJ: Prentice-Hall.

McGrath, J. E., & Hollingshead, A. B. (1994). *Groups interacting with technology: Ideas, evidence, issues, and an agenda.* Thousand Oaks, CA: Sage.

McGuire, T. W., Kiesler, S., & Siegel, J. (1987). Group and computer-mediated discussion effects in risk decision making. *Journal of Personality and Social Psychology, 52,* 917–930.

McLeod, P. L. (1992). An assessment of the experimental literature on electronic support of group work: Results of a meta-analysis. *Human-Computer Interaction, 7,* 257–280.

McLeod, P. L., Baron, R. S., Marti, M. W., & Yoon, K. (1997). The eyes have it: Minority influence in face-to-face and computer-mediated group discussion. *Journal of Applied Psychology, 82,* 706–718.

Ocker, R. J., & Yaverbaum, G. J. (1999). Asynchronous computer-mediated communication versus face-to-face collaboration: Results on student learning, quality and satisfaction. *Group Decision and Negotiation, 8,* 427–440.

Olaniran, B. A. (1996). A model of group satisfaction in computer-mediated communication and face-to-face meetings. *Behaviour & Information Technology, 15,* 24–36.

O'Reilly, C. A., & Roberts, K. H. (1976). Relationships among components of credibility and communication behaviors in work units. *Journal of Applied Psychology, 61,* 99–102.

Potter, R. E., & Balthazard, P. A. (2002). Virtual team interaction styles: Assessment and effects. *International Journal of Human-Computer Studies, 56,* 423–443.

Probber, J. K., & Foster, L. L. (2000). Examining virtual teamwork: Communication quality, cohesion and process satisfaction. *Journal of e. Commerce and Psychology, 1,* 14–33.

Purdy, J. M., & Nye, P. (2000). The impact of communication media on negotiation outcomes. *International Journal of Conflict Management, 11,* 162–187.

Rogelberg, S. G., Barnes-Farrell, J. L., & Lowe, C. A. (1992). The stepladder technique: An alternative group structure facilitating effective group decision making. *Journal of Applied Psychology, 77,* 730–737.

Rogelberg, S. G., & O'Connor, M. S. (1998). Extending the stepladder technique: An examination of self-paced stepladder groups. *Group Dynamics: Theory, Research, and Practice, 2,* 82–91.

Smith, J. Y., & Vanecek, M. T. (1988). Computer conferencing and task-oriented decisions: Implications for group decision support. *Information & Management, 14,* 123–132.

Smith, J. Y., & Vanecek, M. T. (1990). Dispersed group decision making using nonsimultaneous computer conferencing: A report of research. *Journal of Management Information Systems, 7,* 71–92.

Straus, S. G. (1996). Getting a clue: The effects of communication media and information distribution on participation and performance in computer-mediated and face-to-face groups. *Small Group Research, 27,* 115–142.

Straus, S. G., & McGrath, J. E. (1994). Does the medium matter? The interaction of task type and technology on group performance and member reactions. *Journal of Applied Psychology, 79,* 87–97.

Thompson, L. F., & Coovert, M. D. (2002). Stepping up to the challenge: A critical examination of face-to-face and computer-mediated team decision making. *Group Dynamics: Theory, Research, and Practice, 6,* 52–64.

Thompson, L. F., & Probber, J. K. (2001, April). *Out of sight, out of mind: Recalling virtual team contributions.* Paper presented at the 16th Annual Meeting of the Society for Industrial and Organizational Psychology, San Diego, California.

Valacich, J. S., & Schwenk, C. (1995). Devil's advocacy and dialectical inquiry effects on face-to-face and computer-mediated group decision making. *Organizational Behavior and Human Decision Processes, 63,* 158–173.

Walther, J. B., & Burgoon, J. K. (1992). Relational communication in computer-mediated interaction. *Human Communication Research, 19,* 50–88.

Warkentin, M. E., Sayeed, L., & Hightower, R. (1997). Virtual teams versus face-to-face teams: An exploratory study of a Web-based conference system. *Decisions Sciences, 28,* 975–996.

Weisband, S. P. (1992). Group discussion and first advocacy effects in computer-mediated and face-to-face decision making groups. *Organizational Behavior and Human Decision Processes, 53,* 352–380.

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