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# The Impact of Group Size and Social Presence on Small-Group Communication

## Does Computer-Mediated Communication Make a Difference?

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This study evaluates the impact of varying group size and social presence on small-group communication. It compares key communication factors—face-to-face (FtF) without computer-mediated communication (CMC) support, FtF with CMC support, and virtual with CMC support—on two different small group sizes (3 and 6). Results indicate that smaller groups establish and maintain higher levels of communication quality, and FtF with CMC support groups have higher levels of communication quality than virtual with CMC support groups; however, no significant difference between traditional FtF groups and virtual groups with CMC support was found. Also, CMC minimized the impact of increased group size. Process losses that a larger FtF group might ordinarily experience can be reduced through the use of CMC. These results should help project managers plan for and deal with the difficulty of communication between project group members in virtual environments.

***Keywords:*** *computer-mediated communication (CMC); small-group communication; virtual teams; social presence; social presence theory (SPT); heuristic evaluation (HE)*

The use of groups for project work has become a vital component of today's workplace, especially in light of the global world economy (Bandow, 2001). Recent estimates conclude that group-based work methods exist in nearly 70% of U.S. firms (Kirkman & Rosen, 1999; Stewart & Barrick, 2000). Collaborative work involves sharing ideas, knowledge, competencies, and information to accomplish a task or goal (Nunamaker, Dennis, Valacich, Vogel, & George, 1991).

For collaboration to be successful, however, effective communication among group members is necessary (Roberts, Lowry, & Sweeney, 2006). The importance of having effective group communication increases with greater complexity in the exchange of information in verbal or digital communication (Dommel & Garcia-Luna-Aceves, 2000). Group members must be able to clearly and explicitly exchange information for communication to effectively support collaboration. Unfortunately, most groups experience process losses that undermine effective communication; such losses include conformity (Hackman & Kaplan, 1974), evaluation apprehension (Diehl & Stroebe, 1987; Lamm & Trommsdorff, 1973), and production blocking (Diehl & Stroebe, 1987). The impact of these phenomena may vary depending on task, group size, or level of social presence (Andres, 2006; Roberts, Cheney, & Sweeney, 2002; Roberts, Cheney, Sweeney, & Hightower, 2005; Roberts et al., 2006).

Although task and group size are easily defined in most cases, modern technologies have created a great range of social presence situations in which team communication can occur. For instance, when communication is face-to-face (FtF), participants are collocated and perceive the physical presence of others in the room; however, when communication is digital (computerized), there is often a reduction in the number and type of cues that facilitate communication through nonverbal channels that are harder or perhaps impossible to perceive when a group is distributed (Daft, Lengel, & Trevino, 1987). Digital communication can take many forms. For the purposes of this study, we define computer-mediated communication (CMC) as "any form of communication between two or more individuals who interact and/or influence each other via computer-supported media" (from Wikipedia). The goal of this

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study is to determine the impact of social presence and group size on group communication within small groups conducting a complex systems development task by comparing FtF- and CMC-supported groups.

## Social Presence

Two early schools of thought attempted to explain a medium's effect on a message and on the communicators' evaluations. One asserts media vary in terms of interaction process efficiency in that they provide different numbers of channels and support transmission of different nonverbal cue types. The other asserts that media differ based on the quantity of nonverbal communication they can transmit. Short, Williams, and Christie (1976) combined the two and suggested social presence as a construct to classify communication media and their social impacts. Biocca, Harms, and Burgoon (2003) define social presence as a "sense of being with another" (p. 456). Adding to this, we adopt a more explicit definition of social presence as the degree to which a communication medium allows group members to perceive (sense) the actual presence of the communication participants and the consequent appreciation of an interpersonal relationship, despite the fact that they are located in different places, that they may operate at different times, and that all communication is through digital channels.

Yoo and Alavi (2001) have called for additional research on media conditions and social factors that influence how individual group members perceive and use technology and for additional research involving social structures created by CMC. Communication patterns clearly fall within this realm. Yet instead of focusing on the social structures created by CMC, almost all of the research into CMC and group size has focused on productivity gains through tasks such as brainstorming (Aiken, Krosp, Shirani, & Martin, 1994; Dennis & Valacich, 1993; Gallupe et al., 1992; Valacich & Dennis, 1994; Valacich, Wheeler, Mennecke, & Wachter, 1995) and the elimination of process losses—largely ignoring the group communication aspects of collaboration. Several studies have examined group member or minority influence in group decision making (Dennis, Hilmer, & Taylor, 1998; McLoed, Baron, Marti, & Yoon, 1997), and others have looked at group member voice in decision making (Roberts et al., 2006). Burgoon, Bonito, et al. (2002) evaluated many communication factors of collaborative groups but did not address the impact of group size. One unique

contribution of this research is that it studies the upper limits of small group size in a task to discern if and how communication patterns break down when group size increases. It is important for those who engage in virtual group collaboration to know the point of diminishing returns, after which the addition of more group members may lead to poorer quality communication, to ensure that resources are not applied inefficiently.

Given this gap in the literature regarding group communication, social presence, and group size in CMC groups, this research examines the perceptions of the quality of group communication with varying small group sizes and levels of social presence. The three communication modes we examine are (a) traditional FtF or proximate work without CMC support, (b) proximate work with CMC support, and (c) virtual work with CMC support.

The remainder of this article provides literature and theoretical background to explain and predict how variations in group size and social presence affect perceived communication outcomes in small groups, performing the unique collaborative task of heuristic evaluation (HE). HE is a small-group-based assessment technique for evaluating the usability of information system interfaces. We describe a laboratory experiment to test the hypotheses and discuss the results, along with their contributions to theory, implications for practice, limitations, and opportunities for future research.

## Theory and Hypotheses

### Group Communication Constructs

Before making our theoretical predictions, we will explicitly define the constructs of interest in this study. The scope of our research focuses on group-communication constructs that are perceived by group members. The phenomenon of interest in this study is perceived communication quality, which refers to a group member's evaluation of the level of group discussion effectiveness and development (Burgoon, Bonito, et al., 2002; Burgoon, Burgoon, Broneck, Alvaro, & Nunamaker, 2002). Communication quality is composed of several subconstructs, including quality, appropriateness, richness, openness, and accuracy.

Group discussion quality is the group members' evaluation of the level of effectiveness and satisfaction experienced during group discussions and discussion development (Burgoon, Bonito, et al., 2002; Burgoon, Burgoon, et al., 2002). A high-quality group discussion generates multiple perspectives, where shared knowledge allows members to understand the problem

space and to successfully define the problems (Burgoon, Bonito, et al., 2002; Burgoon, Burgoon, et al., 2002).

Communication appropriateness reflects how suitable, applicable, and satisfying a group's communication is to its members (Burgoon & Walther, 1990). Appropriate communication includes implicit or explicit references to some level of behavioral engagement, such as politeness or social norms, as an element of social presence (Burgoon & Dunbar, 2000). Appropriate communication can be directly related to group judgment on a particular topic (Burgoon, Bonito, et al., 2002). Although appropriate communication can facilitate group processes, inappropriate communication can create process losses such as flaming (Nunamaker et al., 1991), avoiding conflict (Mosvick & Nelson, 1987), listening issues (Mosvick & Nelson, 1987), and communication apprehension (Jablin & Sussman, 1978).

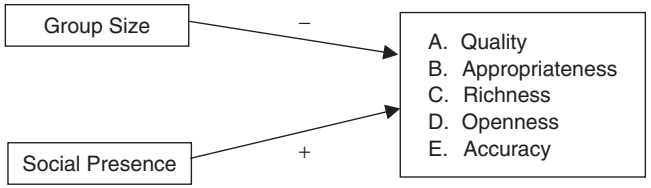
Communication richness refers to the exchange of on-topic, detailed responses and vivid messages within the group (Burgoon, Bonito, et al., 2002). Rich communication has been shown to increase group coordination and pooling of individual information (Burgoon, Burgoon, et al., 2002). This pooling of information by individual group members is a key factor that can make group performance exceed that of individual performances (e.g., Ackerman & McDonald, 2000; Wegner, Erber, & Raymond, 1991).

Communication openness is the willingness of a group member to be receptive to the communication of others (O'Reilly & Roberts, 1977). Gibb (1960) found openness to be a central variable in group process. One who is open to experience evaluates threats more accurately and tolerates change more graciously than does someone who is more closed to experience. Openness allows group members to deal with problems in a mature manner (Haney, Banks, & Zimbardo, 1973). Rogers and Rogers (1976) considered openness as the polar opposite of defensiveness. Accordingly, in an open environment, people are more able to explore their own ideas, the group's perceptions of their ideas, and the ideas of others in the group.

Accuracy is the degree to which information in a group is correctly communicated and properly understood (O'Reilly & Roberts, 1977). The context of the communication is important because the more noise and distraction that is present, the less clear and accurate the message becomes (Rogers & Rogers, 1976). Accurate communication logically affects the quality of decisions and the amount of time required to clarify information.

Given these constructs, we have developed a research model, as summarized in Figure 1.

**Figure 1**
**Theoretical Model**




## Communication Predictions Based on Group Size

Only limited research has considered the effects of group size on group communication specifically using CMC. LePine and Dyne (1998) examined the interactions of permanent, highly interdependent industry work groups. The two key variables they examined were the size of work groups and the style of management that was employed (traditional decision making or self-managed groups). Their findings confirm previous research that indicates that increased group size increases process losses in verbally interacting groups (Bouchard & Hare, 1970; Steiner, 1972). For example, the number of ideas contributed per person decreases sharply as group size increases (Steiner, 1972). In addition, the perceived responsibility for outcomes is negatively related to group size (Latane & Wolf, 1981). Finally, larger groups have been found to have more difficulty identifying contributions made by individual members, and members feel more anonymous and less involved in larger groups than they do in smaller groups (Latane & Wolf, 1981).

In addition, research indicates that group size is negatively correlated to the generation of ideas (Gallupe et al., 1992; Valacich et al., 1995) and is positively correlated to the degree of conflict within a group (Steiner, 1972; Valacich et al., 1995). Essentially, process losses tend to increase with group size in larger FtF groups (Gallupe et al., 1992; Hackman & Vidmar, 1970; Valacich et al., 1995). Typically, production blocking occurs in FtF groups and with larger group sizes (Gallupe, Cooper, & Grisé, 1994) because members are forced to speak sequentially; thus, the time to evaluate each other's opinion is limited (Diehl & Stroebe, 1987). However, other studies regarding group size have illustrated that CMC can help large

groups outperform non-CMC large groups—particularly in terms of brainstorming productivity (e.g., Dennis, Heminger, Nunamaker, & Vogel, 1990; Dennis & Valacich, 1993; Gallupe et al., 1992; Valacich, Dennis, & Nunamaker, 1992; Valacich et al., 1995).

As group size increases, almost every group experiences some degradation in group communication processes, even with CMC support (Chidambaram & Tung, 2005). Many of the process losses that occur from group size increases can be attributed to the social phenomena of evaluation apprehension, production blocking (Aiken et al., 1994; Nunamaker et al., 1991), and social loafing (Chidambaram & Tung, 2005). Evaluation apprehension occurs when group members withhold ideas because they fear they may be criticized by other group members (Diehl & Stroebe, 1987; Lamm & Trommsdorff, 1973). This phenomenon is typically stronger in FtF groups than in virtual groups (Valacich, George, Nunamaker, & Vogel, 1994). Production blocking occurs when potentially good or creative ideas are suppressed or forgotten when a person is busy listening to other group members—particularly if a speaker dominates the conversation or takes too long to express his or her ideas (Diehl & Stroebe, 1987; Lamm & Trommsdorff, 1973). Social loafing increasingly occurs in larger groups where group members feel they have diminished responsibility and do not need to contribute to their full potential (Chidambaram & Tung, 2005).

Given this background, we propose that group size is negatively correlated to communication quality in small groups. Smaller groups naturally allow for more individual "airtime" than larger groups regardless of technology support. This is because of the decreased opportunities for interactivity and reciprocity among members of larger groups. The differences caused by group size will have a direct impact on the quality of the communication among group members. Burgoon, Bonito, et al. (2002) found that participation in smaller group discussions where members have influence over final decisions generally causes more appropriate, profound, and accurate communications. However, their findings were limited to variations of CMC and a decision-making task (desert survival) performed in dyads where one member was a confederate. With these previous findings in mind, we hypothesize:

*Hypothesis 1 (H1):* Three-person small groups will report (a) higher quality of group discussions, (b) more appropriate communication, (c) richer communication, (d) greater communication openness, and (e) more accurate communication than six-person small groups throughout the entire task of HE.

## Communication Predictions Based on Level of Social Presence

An early influential theory of presence was the social presence model developed by Short et al. (1976). This model defined social presence as the subjective quality of the medium or the extent to which the medium allows intimacy and immediacy. Although this research was focused primarily on telephone, audio, and video links, researchers have found that the social presence model applies to CMC as well. Social presence theory (SPT) states that media low in social presence may not be suitable for intersubjective interpretation when interactivity and reciprocity are needed in communication (Miranda & Saunders, 2003; Short et al., 1976). Central to SPT is the belief that the presence of the sender influences the recipients' understanding of the message (Miranda & Saunders, 2003). Communication media with more available cues generate a higher level of social presence than those with fewer cues, thus leading to stronger social pressure and normative influence on group members (Burke & Chidambaram, 1999; Miranda & Saunders, 2003; Riegelsberger, Sasse, & McCarthy, 2005; Tan, Wei, Watson, Clapper, & McLean, 1998). Accordingly, traditional, unmediated FtF verbal communication provides the highest social presence (Miranda & Saunders, 2003), whereas computer-supported media provide lower social presence, and virtual groups also experience relatively low social presence (Burke, Aytes, Chidabaram, & Johnson, 1999; Burke & Chidambaram, 1999; Jarvenpaa & Leidner, 1999; Miranda & Saunders, 2003; Roberts et al., 2006).

Dennis and Kinney (1998) suggest that being aware of the social presence of a medium may be important to understanding group tasks. Social presence research indicates that group performance improves when a medium's ability to transmit social presence matches the social needs of a task (Christie, 1985). Low social presence can decrease group member performance by allowing specific comments or information to be ignored completely or delayed.

Related to social presence, high-quality group discussions generate multiple perspectives—involving interaction and reciprocity—where shared knowledge allows for understanding and the successful definition of problems (Burgoon, Bonito, et al., 2002). Because lower social presence results in fewer social cues, it is likely to generate less interaction and reciprocity that is required for high-quality communication. Complementary research shows that FtF communication can enhance communication overall by facilitating social judgments (Burgoon, Burgoon, et al., 2002).

Supporting research illustrates that a lower level of social presence in virtual teams can result in diminished communication quality (Roberts

et al., 2006), whereas FtF communication can enhance communication quality (Burgoon, Bonito, et al., 2002). Studies have also revealed the powerful effect of FtF discussion on cooperation choices in social dilemmas (Orbell, Dawes, & van de Kragt, 1988) and on coordinating the efforts of highly interdependent groups such as juries, aircraft crews, and research teams (Tushman, 1979). FtF communication has also been found to be a powerful tool in developing and maintaining group culture, authority, and tacit norms (Levitt & March, 1988). In contrast, physical distance among members generally means that the shared social setting is at a more abstract or symbolic level than for members present at the same geographical location (Burgoon, Bonito, et al., 2002; Dennis & Valacich, 1999). Furthermore, the natural tendency to establish local territories may interfere with coworkers' identification with the larger collective in virtual groups (Brown & Wade, 1987).

FtF teamwork can be superior to virtual teamwork in terms of social presence (e.g., Burke & Chidambaram, 1999; Miranda & Saunders, 2003) and related communication processes, yet it is not necessarily superior in terms of other aspects of group processes such as more equal participation (McGuire, Kiesler, & Siegel, 1987; Siegel, Dubrovsky, Kiesler, & McGuire, 1986), productivity (Nunamaker et al., 1991), cost (Olson & Olson, 2000), and task focus (Archer, 1990).

Turning from considerations of work mode, it also should be noted that traditional electronic technologies have been considered to have low social presence because of their low media richness (Daft & Lengel, 1986). Yet contemporary CMC has been shown to provide more social presence than earlier electronic media. Key social presence features of CMC include parallelism (Dennis, Wixom, & Vandenberg, 2001), group memory, self-scribing, group awareness, and anonymity. Several of these features can offset the negative effects caused by FtF communication. For example, Lowry and Nunamaker (2003) found that groups that use a collaborative writing tool (that uses a shared interface that provides the above-listed features) will experience higher quality outcomes than groups that use Microsoft Word in terms of productivity, document quality, relationships, and communication. The level of satisfaction was not enhanced by using the collaborative writing tool.

Parallelism is the group members' ability to simultaneously contribute information without waiting for other group members (Dennis et al., 2001). Group memory (Dennis & Garfield, 2003; Zigurs & Buckland, 1998) is provided by storing typed comments electronically for documentation and future use. Self-scribing is the ability of each individual to type comments directly into group memory (Rodgers, Dean, & Nunamaker, 2004). Group

awareness is the ability to know what other group members are doing, which provides tacit communication and coordination (unspoken and understood) that improves interactivity and improves overall group results (Beaudouin-Lafon & Karsenty, 1992; Dourish & Bellotti, 1992; Lowry & Nunamaker, 2003; Weisband, 2002). Finally, anonymity allows group members to contribute to group discussions and collaborations without being identified. In many cases, anonymity (Connolly, Jessup, & Valacich, 1990; Hayne & Rice, 1997) increases the motivation of individual group members to participate (Dennis et al., 2001).

Social presence and media richness are related, but it is important to not confuse them. Media richness is defined as the extent to which a medium provides communication capabilities for those using the medium (Daft & Lengel, 1986). Thus, one might argue the CMC condition of FtF work had the highest media richness because it had the most communication capabilities available (not just nonverbal cues from normal FtF interaction but also written text). However, having the most communication capabilities at one's disposal does not always translate into the highest productivity. It is possible for a medium to be so rich that it is distracting or divides attention from a task (Robert & Dennis, 2005). For example, this might be seen when students use laptops in a classroom where interactive verbal discussion is taking place. It is important to note in the context of our experiment that the FtF groups with CMC support should have the highest level of social presence because of the multiple communication channels available, although virtual groups with CMC support will have the lowest level of social presence because of the lean media being used.

Based on the previous literature results, we expect that higher levels of social presence will improve communication among group members. Operationalizing our social presence proposition leads to Hypotheses 2a through 2e.

*Hypothesis 2 (H2):* Groups with higher levels of social presence will report (a) higher quality discussions, (b) more appropriate communication, (c) richer communication, (d) greater openness, and (e) more accurate communication than groups with lower levels of social presence throughout the entire task of HE.

# Method

## Participants

The participants in this experiment were students in a sophomore-level information systems class at a large midwestern university. Approximately

**Table 1**
**Number of Treatment Groups**

| Group Size | A: Traditional Face-to-Face | B: Face-to-Face with CMC Support | C: Virtual With CMC Support |
|---|---|---|---|
| Small[a] | 32 | 26 | 17 |
| Small[b] | 10 | 11 | 10 |

Note: CMC = computer-mediated communication.
a. $n = 3$.
b. $n = 6$.

500 students were enrolled in the course (in two sections over two semesters). The researchers received human subjects approval for student participation as part of the course. All participants had the option to participate in this HE experiment, or an alternative assignment, for course credit for an inconsequential amount of their course grade. Those who chose to participate gave informed consent. Those who chose not to participate were given an alternative assignment designed to be similar in scope and effort to participation in this study. A total of 439 students participated in the study. The following information comprises the demographic data of our participants: age ($M = 20.2$, $SD = 2.0$), GPA ($M = 3.25$, $SD = 0.42$), years of education ($M = 13.7$, $SD = 1.2$), years of work ($M = 4.4$, $SD = 2.6$), and gender (55% male, 45% female). Some participants' data were dropped for failure to assemble into groups of 3 or 6 members because of absent participants or unbalanced numbers of students in a session. Groups with fewer than 3 members or 6 members were allowed to complete the experiment for credit, but their results were dropped from the data analysis. Table 1 shows the number of groups in each condition and treatment. These problems were distributed equally across experimental sessions. The demographic data across sessions were nearly identical. All participants were randomly assigned to a group with blocking to control for gender, prior experience, and GPA differences. These differences were tested by splitting the sample and making comparisons based on gender, prior experience, and GPA. The results indicated a homogenous sample without gender, experience, or GPA differences.

## Task Overview

Participants were asked to use a technique called heuristic evaluation (HE) to evaluate a Web site with many subpages or linked pages. HE was

chosen for this experiment because of its efficient, economical, and user-friendly characteristics and its effectiveness in group settings (Nielsen & Molich, 1990). These characteristics make it easy for novices to understand, learn, and perform the evaluation.

HE is typically based on 10 simple heuristics of usability (Nielsen, 1994). Two examples of the key heuristics are that interfaces should (a) allow the user to easily understand what the system is doing (provide visibility of system status) and (b) provide consistent standards for terminology, button layouts and names, and font sizes, among other items (consistency and standards). HE aims to provide some guidelines for design and to allow for the evaluation of usability problems early and quickly in a design process.

The traditional process of HE involves three initial steps that are conducted with non-CMC software, such as spreadsheets, word processors, or paper and pencil (Nielsen & Molich, 1990). In Step 1, group members evaluate the target interface or interfaces separately, without talking to each other or seeing each other's work. In Step 2, group members meet FtF to reconcile and discuss their evaluation results, remove duplicate heuristic violations, create a combined violation list, and assign severity ratings to each violation. Finally, in Step 3, the heuristic violation list is given to the system development team, which makes the necessary improvements to the interface. This research focuses on the key group processes in Steps 1 and 2. Step 1 in this study included a manipulation in which control groups followed the traditional approach of not meeting with each other, speaking to each other, or seeing each other's work. The CMC groups also do not meet or speak, but they experienced group awareness and thus tacit communication, through parallelism, group memory, self-scribing ability, group awareness, and anonymity.

All participants evaluated a series of Internet-based interfaces that were designed to include heuristic violations varying in complexity and severity. The participants' main task was to identify as many of these violations as they could. The interfaces were designed so that interface design violations could be recognized through application of the heuristics explained in the training session and without the need for any business, system development, or content expertise.

## Treatments

The study used a $2 \times 3$ factorial experimental research design. The study had two levels of small groups (3 and 6) and the three treatment combinations of social presence. The treatments had three possible conditions:

(a) control FtF groups that used non-CMC (Word), (b) FtF groups that used CMC, and (c) virtual groups that used CMC. Participants were randomly assigned to each treatment.

There are several reasons why we specifically chose to compare groups of size 3 and 6. First, Nielsen and Molich (1990) found in four separate experiments that 5 was the group size at which the productivity, in terms of identifying errors, of groups performing HE started to drop off dramatically. Second, the selection of a top size of 6 is keeping to the norm of small group research being conducted in short experimental times. Given the time frame of our study, a small group beyond 6 members would not normally be able to establish communication channels among individual group members.

Collaboratus was chosen as the CMC tool for our experimental conditions because its functionality and control features matched the needs of the experiment. In particular, Collaboratus supports both FtF and Internet-based virtual group work and provides the key CMC features predicted to increase social presence, as discussed in the literature: parallelism, group memory, self-scribing ability, group awareness, and anonymity (Lowry & Nunamaker, 2003; Roberts et al., 2006). In addition, Collaboratus permits experimental control of communication through which participants can see the contributions of others without being able to use direct communication (i.e., we did not permit notes, discussion boards, annotations, or other types of communication). Finally, in direct contrast to Microsoft Word (which does not provide these features), Collaboratus provided increased group awareness and coordination (Lowry & Nunamaker, 2003). CMC tools with similar capabilities should produce similar results under these conditions.

Following other related studies (e.g., Dennis & Kinney, 1998), we operationalized social presence in this study by using three communication settings: proximate FtF groups without support of CMC, proximate CMC-supported groups, and virtual CMC-supported groups. CMC with these features provides increased social presence by virtue of increased media richness. Although these features are not measured in this study, the prior studies listed have confirmed their importance. One can conclude that an environment that combines FtF with CMC should have a higher level of social presence than a traditional FtF environment. Table 2 overviews the social presence that should occur for each condition and across the two steps.

*Treatment 1 (control): Proximate groups without CMC support*. Control groups completed the HE process FtF using a non-CMC tool, Microsoft Word, to emulate the traditional HE method. The use of Word did not have

**Table 2**
**Overview of Social Presence Across Conditions and Steps**

| | Step 1 | | Step 2 | |
|---|---|---|---|---|
| Condition | Social Presence | Other | Social Presence | Other |
| Proximate no CMC, but laptop support | None (pure nominal groups) | No communication | High | FtF interactions somewhat diminished by software interaction with Word |
| Proximate with CMC | Low (CMC-supported nominal groups) | Group memory, group awareness | High + | FtF interactions with second lean channel provided by CMC—Collaboratus |
| Virtual with CMC | Low (CMC-supported nominal groups) | Group memory, group awareness | Moderate | Virtual chat interactions using Netmeeting and second lean channel provided by CMC—Collaboratus |

Note: CMC = computer-mediated communication; FtF = face-to-face.

any special significance because, in theory, we would expect similar results if the Word groups had used other commonly used non-CMC tools (e.g., Excel or Wordpad). Importantly, Word groups used a similar hierarchical layout for recording HE violations as the Collaboratus groups (similar to Windows Explorer). The key difference was that the Word groups did not have any social presence features in Step 1, whereas the CMC groups did have these features.

In the first step of the experiment, the control groups performed the Web site evaluation in proximate groups using the traditional HE process of nominal groups; thus, they recorded their bugs (violations of the given heuristics) individually using Word and without talking to other group members. In the second step of the experiment, these control groups discussed the bugs they found FtF and then combined the bugs into one Word document.

*Treatment 2: Proximate groups with CMC support*. Groups in the first experimental treatment performed HE in proximate groups working anonymously and synchronously in Collaboratus. This tool allowed participants to see the contributions of others in Step 1 but did not allow for direct communication (e.g., notes, discussion, annotations, etc.). These groups discussed their violations FtF during Step 2 and compiled the violation list into one final Collaboratus document, similar to how the control groups did the same in Word.

*Treatment 3: Virtual groups with CMC support*. Groups in the second experimental treatment performed HE in Step 1 anonymously and synchronously via Collaboratus. These treatment groups had no explicit communication capabilities during Step 1, similar to the proximate Collaboratus treatment groups. The primary differences between the first two treatments and this third treatment occurred during Step 2. Unlike the previous conditions, in Step 2, these virtual treatment groups were asked to discuss their observed violations and to consolidate their violation lists using the chat features of Microsoft NetMeeting, without knowing the locations or identities of their fellow group members. As such, this treatment involved only CMC, without verbal communication or nonverbal communication cues. These groups combined their violation lists into one final Collaboratus document, similar to Treatments one and two.

## Experimental Training and Procedures

Several procedures were employed to increase experimental control. First, an entire class lecture session was dedicated to providing training to all participants on HE. The training session provided many heuristics violation examples using screen shots with real interfaces. Nielsen's (1994) 10 basic heuristics were each explained. In addition, participants were given take-home review sheets with examples to reinforce their training.

Second, each session (consisting of 20-30 participants) was dedicated to only one experimental condition to avoid mixing experimental conditions in the same session. Participants were not informed that other experimental conditions existed; rather, all students were told that they would have the opportunity to practice HE in the lab.

Third, each experimental session was carefully scripted and led by a trained facilitator with two graduate assistants. The same facilitator and assistants were used for every session. The facilitator provided a brief introduction that indicated the purpose, rules, and required processes for each session.

Fourth, the participants received a brief, just-in-time, scripted training session on the tools they were to use (i.e., Word, Collaboratus, and NetMeeting) for their assigned treatment condition. The two-step process involved in the study was explained, followed by an intensive training session on the particulars of conducting Step 1. Specifically, participants were shown how to record and categorize the violations they found (in Word or Collaboratus). After receiving these instructions, all participants were allowed exactly 30 minutes to conduct Step 1. All participants in this step were anonymous and had no form of direct communication. Distributed participants sat physically apart from their fellow group members so they would not know who they were working with. After completing Step 1, training was provided to explain how to conduct Step 2. In all cases, Step 2 required that participants consolidate individual work generated in Step 1 into a group final response. This consolidation effort included removing duplicates and resolving disputes about the heuristic violation categorizations. Participants were allowed 10 minutes to complete Step 2. No one was permitted to ask the facilitator questions concerning HE at any time, ensuring that all groups received exactly the same information. The only communication allowed at this point during Step 2 related to the consolidation of bugs.

Fifth, all participants were encouraged to take the experiment seriously because they would be evaluated based on the number of unique bugs (factoring out incorrectly reported bugs, duplicates, etc.) their group reported. This evaluation approach motivated groups to identify real bugs rather than simply accumulate a long list of potential bugs. Although the incentive for a high grade was intended to be motivational to all participants, given that participation in this exercise was optional, the overall effect of the experiment on the students' final grade was preplanned to be inconsequential. This was not revealed to the participants until a debriefing following the completion of all administrations of the experiment.

## Data Collection

After completing Step 2, all participants were asked to complete a questionnaire that included a set of items that indexed the various aspects of communication of interest in this study. These items included group discussion quality (Burgoon, Bonito, et al., 2002; Burgoon, Burgoon, et al., 2002), communication appropriateness (Burgoon & Walther, 1990), and communication richness (Burgoon, Bonito, et al., 2002). In addition, scales concerning information accuracy and communication openness from O'Reilly and Roberts (1977) were also used. Each scale used a 7-point Likert-type

**Table 3**
**Communication Survey Scales**

| | |
|---|---|
| Group discussion quality (Burgoon, Bonito, et al., 2002; Burgoon, Burgoon, Broneck, Alvaro, & Nunamaker, 2002) | |
| The overall quality of the group discussions was good | poor. |
| The outcome of the group discussions was unsatisfactory | satisfactory. |
| The execution of the group discussion was competent | incompetent. |
| The development of group discussion contents was careless | careful. |
| Communication appropriateness (Burgoon & Walther, 1990) | |
| The group discussions were appropriate | inappropriate. |
| The group discussions were suited to the topic | off topic. |
| The group discussions were unsatisfying | satisfying. |
| Communication richness (Burgoon, Bonito, et al., 2002) | |
| In terms of our group's communication, it can be said that . . . | |
| Responses . . . | |
| lacked details | were filled with details. |
| Messages were . . . very vivid | unclear. |
| Forms of expression had . . . high variety | high redundancy. |
| The amount of information was . . . lean | rich. |
| Openness (O'Reilly & Roberts, 1977) | |
| It was easy to communicate openly to all members of this group. | |
| Communication in this group was very open. | |
| I found it unenjoyable to talk to other members of this group. | |
| When people communicated to each other in this group, there was a great deal of understanding. | |
| It was difficult to ask advice from any member of this group. | |
| Accuracy (O'Reilly & Roberts, 1977) | |
| The information I received was generally accurate. | |
| I can think of a number of times when I received inaccurate information from others in the group. | |
| It was often necessary for me to go back and check the accuracy of information I received. | |
| I sometimes felt that group members didn't understand the information received. | |
| The accuracy of information passed among group members did not need to be improved. | |

Note: All items were on a scale of 1 (*strongly disagree*) to 7 (*strongly agree*).

scale with positive and negative anchors. Several items on each scale were reverse coded to ensure that the scale represented the same continuum. The items for each scale are presented in Table 3.

# Analysis and Results

## Method of Analysis

An initial assessment of each scale was conducted by calculating the internal reliability (Cronbach's α) of each scale. This procedure resulted in the elimination of one item from the openness scale: "I found it unenjoyable to talk to other members of this group." One item was also eliminated from the accuracy scale: "The accuracy of information passed among group members did not need to be improved."

Because all of the items were collected at the same time, an exploratory factor analysis was conducted to assess and validate the scales. The analysis used the Varimax rotation, and factors were set by eigenvalues greater than 1. One item crossloaded and was eliminated from the study. This item was "The group discussions were unsatisfying . . . satisfying." New reliabilities were calculated for each scale. The resulting Cronbach's alphas are as follows: $\alpha = .82$ (quality), $\alpha = .80$ (openness), $\alpha = .78$ (accuracy), $\alpha = .77$ (appropriateness), $\alpha = .77$ (richness).

A second set of procedures was conducted to determine the level of analysis to be used in the study. Two distinctly different approaches have been suggested in the literature to ascertain the presence of within-group or between-group effects. The first procedure uses an agreement or similarity index (James, Demaree, & Wolf, 1984). This approach uses $R_{wg}$ within group similarity to assess interrater reliability about a single referent. The second approach is the within and between analysis (WABA) approach suggested by Dansereau, Alutto, and Yammarino (1984). The WABA approach conducts a complete analysis for within- and between-group effects. Both approaches were performed for this study.

James et al. (1984) suggest as a rule of thumb that an $R_{wg}$ of .70 is indicative of satisfactory agreement within the set of respondents. All communication variables met this criteria (quality of discussion = .70, appropriateness = .70, richness = .73, openness = .70, and accuracy = .77). These results suggest agreement by group members for each of the variables.

WABA was developed to assess both variation and covariation in variables within and between levels of analysis (Cogliser & Schriesheim, 2000; Dansereau et al., 1984; Yammarino, 1998). In our case, this analysis compared two levels: individuals and groups. The E test and F test under WABA I indicate whether variance is between or within groups or both or neither. Similarly, WABA II assesses covariance. Finally, the WABA equation combines WABA I and WABA II to examine correlation components. For this

study, WABA I results indicated a slight parts or individual result for communication richness, whereas the remaining results were found to be equivocal. WABA II results found slight indicators for wholes or groups for the covariance between group discussion and group work. The final WABA equation produced equivocal results. Dansereau et al.'s (1984) guidance for equivocal results states, "A focus between and within entities is valid" (p. 40). These results indicated a slight move toward the group level when interpreting WABA II. This result, coupled with an analysis of the item anchors for each scale, caused us to select the group level of analysis for all ANOVAs.

A MANOVA procedure was used to test the five primary dependent measures to parse the effect of the dependent communication variables. The MANOVA results revealed explicit differences among the three treatments and the two group size levels for each of the dependent variables. The primary analysis of the experiment involved a two-way ANOVA of the $2 \times 3$ design. As noted, these variables included group size and treatment (level of social presence). These constructs were analyzed at the group level of analysis.

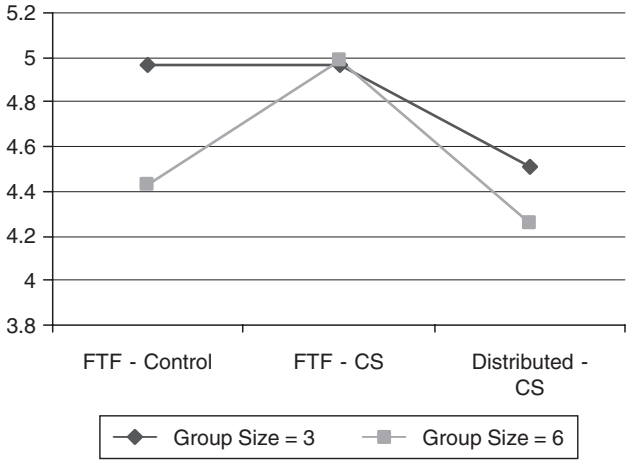
## Quality of Discussion

The two-way ANOVA procedure conducted on the quality of discussion scale revealed a significant main effect for this variable, $F(2, 101) = 3.236$, $p < .05$. There was not a significant main effect for group size (H1a), and the main effect variables were not modified by any significant interaction effect. Tukey's post hoc test indicated a significant difference between Social Presence Treatment 2 and Social Presence Treatment 3, supporting H2a; however, Social Presence 1 did not exhibit a significant difference. Figure 2 details the results for quality of discussion. Table 4 indicates the support of each hypothesis for each construct, and Table 5 shows the mean results for each condition.

## Communication Appropriateness

The two-way ANOVA procedure for communication appropriateness revealed significant effects because of group size, $F(1, 107) = 3.94$, $p < .05$, and treatment, $F(2, 107) = 17.366$, $p < .000$. There were not any significant interaction effects between group size and treatment. As predicted in H1b, the results indicated more appropriate communication for 3-person groups

**Figure 2**
**Discussion Quality Results**




Note: FTF = face-to-face; CS = collaborative software.

than 6-person groups. Tukey's post hoc results also support H2b, with Social Presence Treatment 1 and Treatment 2 having significantly more appropriate communication than Social Presence Treatment 3. No significant difference was found between the two proximate treatments (see Table 5 and Figure 3).

## Communication Richness

The two-way ANOVA procedure conducted for communication richness revealed a significant main effect for the treatment condition, $F(2, 100) = 6.154$, $p < .01$. A significant main effect was not found for group size (H1c). However, the main effect variables were modified by a significant interaction, $F(2, 100) = 3.560$, $p < .05$. Tukey's post hoc test indicated a significant difference between Social Presence Treatment 2 and Social Presence Treatment 3, supporting H2c; however, Treatment 1 was not significantly different from either of the other treatments. Figure 4 details the results for communication richness. Table 5 shows the mean results for each treatment condition.

**Table 4**
**Summary of Hypotheses and Results**

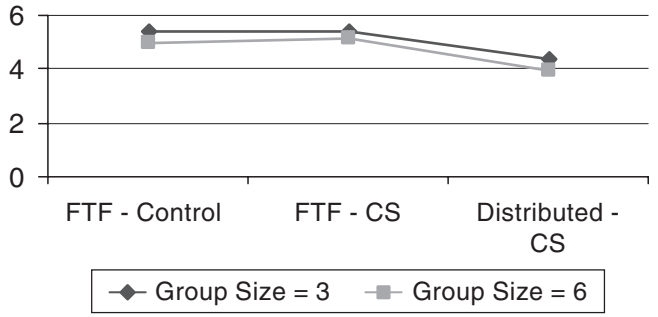
| Hypothesis | Measure | Support |
|---|---|---|
| 1a: Group Size (3) > Group Size (6) | Discussion quality | No |
| 1b: Group Size (3) > Group Size (6) | Appropriateness | Yes |
| 1c: Group Size (3) > Group Size (6) | Richness | No, interaction significant |
| 1d: Group Size (3) > Group Size (6) | Openness | Yes |
| 1e: Group Size (3) > Group Size (6) | Accuracy | Yes |
| 2a: High Social Presence > Low Social Presence | Discussion quality | Yes, B > C |
| 2b: High Social Presence > Low Social Presence | Appropriateness | Yes, A > C, B > C |
| 2c: High Social Presence > Low Social Presence | Richness | Yes, B > C |
| 2d: High Social Presence > Low Social Presence | Openness | No |
| 2e: High Social Presence > Low Social Presence | Accuracy | Yes, A > C, B > C |

**Table 5**
**Factor Mean Scores Across Experimental Conditions for Measures of Communication Quality**

| | Dependent Variables | | | | |
|---|---|---|---|---|---|
| Experimental Conditions | Quality of Discussion | Appropriateness | Richness | Openness | Accuracy |
| Proximate | | | | | |
| 3 persons | 4.97 | 5.36 | 4.58 | 5.90 | 5.41 |
| 6 persons | 4.43 | 4.99 | 3.95 | 4.86 | 4.41 |
| Proximate + CMC | | | | | |
| 3 persons | 4.97 | 5.39 | 4.68 | 5.75 | 5.45 |
| 6 persons | 4.99 | 5.13 | 4.77 | 5.51 | 5.22 |
| Virtual + CMC | | | | | |
| 3 persons | 4.51 | 4.33 | 4.04 | 5.63 | 4.83 |
| 6 persons | 4.26 | 3.97 | 4.26 | 4.91 | 4.34 |

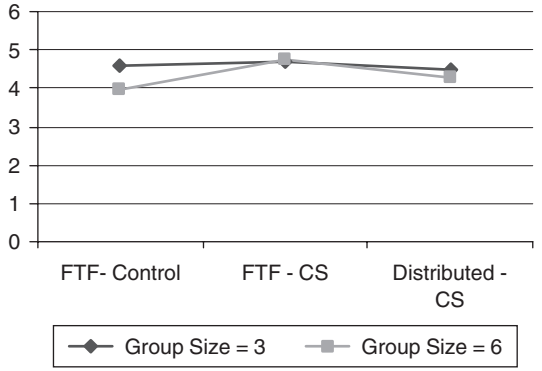
Note: CMC = computer-mediated communication.

**Figure 3**
**Communication Appropriateness Results**




Note: FTF = face-to-face; CS = collaborative software.

**Figure 4**
**Communication Richness Results**

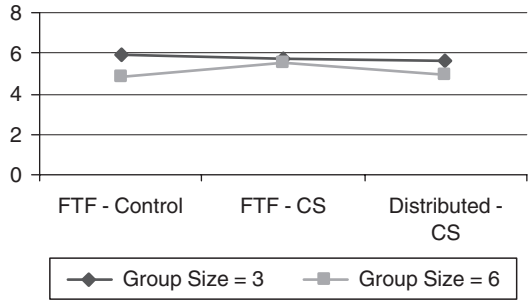



Note: FTF = face-to-face; CS = collaborative software.

## Communication Openness

The two-way ANOVA procedure conducted on the communication openness scale revealed a significant main effect for group size, $F(1, 100) = 17.401$,

**Figure 5**
**Communication Openness Results**



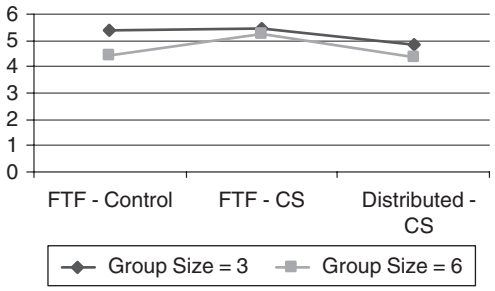

Note: FTF = face-to-face; CS = collaborative software.

$p < .001$. There was not a significant main effect for the treatment, nor was either main effect variable modified by a significant interaction effect. The 3-person groups had significantly more open communication than did the 6-person groups, supporting H1d. Importantly, the social presence treatments did not affect communication openness (H2d). Figure 5 details the results for openness. Table 5 shows the mean results for each treatment condition.

## Communication Accuracy

The two-way ANOVA procedure conducted for communication accuracy revealed significant effects because of group size, $F(1, 107) = 14.521$, $p < .001$, and treatment, $F(2, 107) = 8.085$, $p < .001$. There were not any significant interaction effects between group size and treatment. In support of H1e, the results indicated more accurate communication for 3-person groups than 6-person groups. Tukey's post hoc results also support H2e, with higher social presence conditions (Treatment 1 and Treatment 2) having significantly more accurate communication than the lower social presence condition (Virtual Treatment 3). The results did not reveal a significant difference between the two proximate FtF treatments. Table 5 shows the treatment means, and Figure 6 illustrates the means across treatments.

**Figure 6**
**Communication Accuracy Results**




Note: FTF = face-to-face; CS = collaborative software.

# Discussion

## Contributions to Theory and Practice

A key finding in the study was that the majority of our hypotheses about group size were supported. However, we did not find that discussion quality was significantly improved by simply being in a smaller (3-person) group, although these means were higher than those of larger (6-person) groups. The results indicate that the 3-person groups experienced better communication in regard to appropriateness, openness, and accuracy than did the 6-person groups.

This information would be especially important to establish openness within the group or to reduce complexity in group communication, and it might solve some inappropriate communication problems. For example, inappropriate communication would be more difficult to hide with the reduced opportunity to maintain anonymity in small groups. It should also be noted that in every case the outcome of the communication variables did not drop as much with the group size increase when CMC was introduced. This suggests that although group size increases do decrease quality of communication, CMC minimizes the negative impact. This finding is vital in practice, given the increased use of virtual work groups.

The other communication hypothesis for group size not supported was H1c. However, it appears that CMC actually improved communication richness. One must be careful regarding these results because of the significant interaction among the main effects variables, group size, and treatment. A

close look at the mean results reveals an improvement or at least equal footing in the richness of communication as group size increases if a CMC tool is employed. For instance, using a series of within-treatment, two-sample *t* tests, for Treatment 2 (group size = 3, $M = 4.68$; group size = 6, $M = 4.77$; $t = –0.443$, $p(t) = .660$) and for Treatment 3 (group size = 3 ($M = 4.04$; group size = 6, $M = 4.26$; $t = –0.883$, $p(t) = .440$) this result exists, but Treatment 1 (group size = 3, $M = 4.58$; group size = 6, $M = 3.95$; $t = 3.823$, $p(t) = .0005$) offers an opposite result. These results indicate at least equal footing in communication richness via the use of a CMC tool.

With the social presence hypotheses, we found significant differences for every hypothesis except communication openness between the two CMC treatments. However, we did not find significant differences between the two FtF treatments on any multiple comparison.

In addition, the treatment means indicate that the FtF CMC-supported treatment had higher values for quality and richness than did the FtF without CMC treatment. This is confirmed by the fact that we found significant differences between the two CMC-supported treatments for discussion quality and richness, whereas we did not find a significant difference between the control treatment (1, proximate without CMC support) and the virtual treatment (3). In fact, the virtual treatment outperformed the control proximate treatment with regard to communication richness in 6-person HE groups. This result is very important because it supports the use of virtual teams in the system development process.

A second major point is that our results did not indicate a significant difference in openness among any of the treatments. This clearly indicates that communication openness was not significantly different for virtual groups and FtF groups in this study. This is also a practically significant finding for any organization attempting to use virtual teams because it means that team members can be just as open in virtual settings as in FtF settings.

We also found that the proximate treatments outperformed the virtual treatment in regard to appropriate communication and accuracy. This result should not be surprising, especially in the case of appropriate communication. Collaborative research has revealed both the positive and negative aspects of using CMC. One positive factor was that anonymity was present for group members in the virtual groups. Although anonymity might provide a positive motivator for the participants, it also promotes opportunities for inappropriate communication or even flaming. In regard to communication accuracy, we believe that being proximate presents a different level of accountability. It is more difficult to be inaccurate in a proximate situation than in a virtual one.

A primary contribution of this research is that it shows how variations in social presence and group size affect small-group communication in terms of quality of discussion, communication appropriateness, communication richness, openness, and accuracy. The results from this experimental comparison of CMC groups with traditional FtF groups suggest that positive effects on communication were observed for the virtual groups—especially the 6-person virtual HE groups. It appears that the process losses one might ordinarily see in larger FtF groups performing HE can be limited by the use of CMC. These effects may be manifested through more positive or smoother group communication. In summary, group size and social presence each affect group communication patterns.

## Limitations

The primary limitation of this study is its restricted generalizability. Using a controlled laboratory environment with tightly scripted conditions under a limited time frame causes limited generalizability of the results of this research. We believe that different results may occur in groups larger than 6, in groups that work together during extended periods, in groups that include usability experts, or in groups that perform different tasks.

A similar generalizability limitation involves the use of novice student groups. One accepted method to mitigate this concern is to recruit participants using characteristics representing the population of interest and present them with tasks for which they have the requisite skills and knowledge (Gordon, Slade, & Schmitt, 1986). In this study, student participants clearly represent a subset of the broader population of typical novice end-user evaluators and have the skills and knowledge to perform the tasks assigned. This is a good fit because HE is designed so that novice evaluators can be involved in the evaluation process (Nielsen & Molich, 1990). Given these points, we believe novices serve well as participants for this study. However, we anticipate that experts using HE could provide even stronger results—as seen in Nielsen and Molich (1990).

## Conclusion

This study evaluated the impacts of group size and social presence on group communication. We compared key communication factors (appropriateness, openness, richness, discussion quality, and accuracy) for three different treatments (proximate without CMC support, proximate with CMC support, and virtual with CMC support). In addition, our study evaluated

these impacts with two different group sizes (i.e., 3-member groups and 6-member groups). We found that 3-person groups maintained higher levels of communication quality than did 6-person groups. Discussion quality was not significantly improved by simply being in a 3-person group instead of a 6-person group; however, the other four communication variables of appropriateness, openness, richness, and accuracy were greater within the 3-person groups than in the 6-person groups. This finding is of particular interest to practitioners because it suggests more complex projects may benefit from using much smaller groups.

Similarly, the social presence treatment results found the two-channel FtF with CMC support produced significantly better communication than did the virtual with CMC support treatment for every hypothesis except communication openness, whereas the traditional FtF without CMC support only outperformed the virtual with CMC support treatment with appropriateness and accuracy. This is a significant finding especially for those organizations using virtual groups. Finally, we also found that CMC minimized the impact of group size increases on communication quality. CMC does not completely eliminate the impact of increased group size on communication quality, but it does have positive and practically useful effects.

We believe these findings will help organizations and project groups to better manage their FtF and virtual work groups, thus leading to a greater project success rate. We also believe that future researchers will be able to use these findings to advance their investigations into the relationship between group size and social presence with regard to group communication quality and group performance.

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