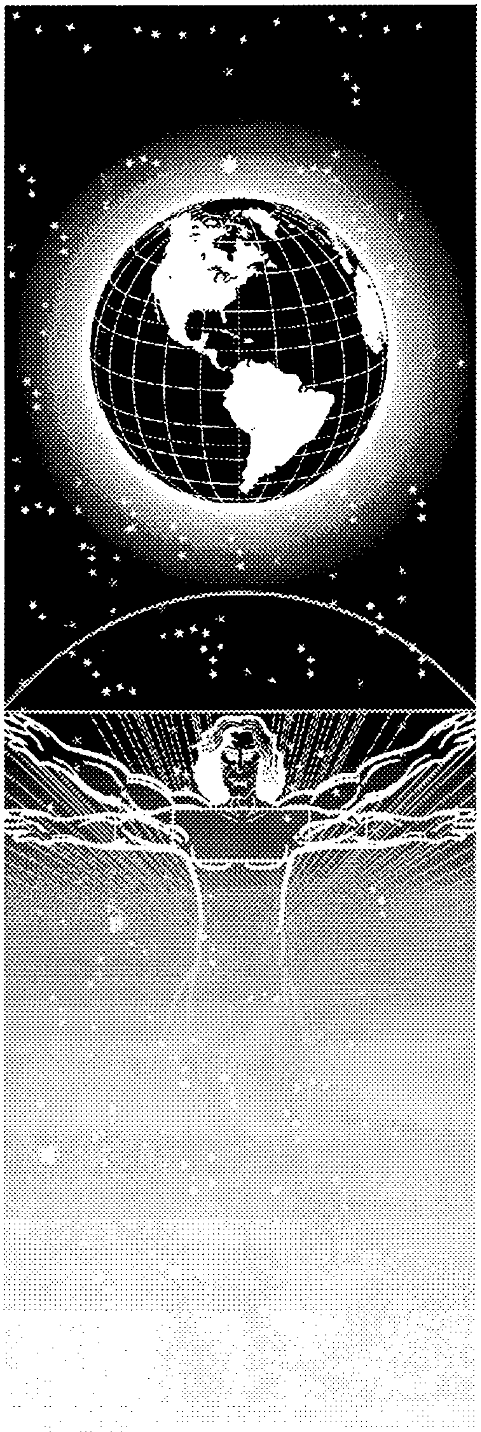
AL/HR-TP-1997-0044



UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

Information Sharing in Face-to-Face, Teleconferencing, and Electronic Chat Groups

Kenneth A. Graetz
Charles Kimble
Pamela Thompson
Julie Garloch

THE UNIVERSITY OF DAYTON
300 College Park
Dayton, Ohio 45469

Edward S. Boyle

HUMAN RESOURCES DIRECTORATE
Logistics Research Division
2698 G Street
Wright-Patterson Air Force Base, Ohio 45433 7604

October 1997

Human Resources Directorate
Logistics Research Division
2698 G Street
Wright-Patterson AFB OH
45433-7604

NOTICES

This paper has been reviewed and is approved for publication.

EDWARD S. BOYLE
Program Manager

LOUIS M. JOHNSON, LT COL, USAF
Acting Chief, Logistics Research Division

PREFACE

This research was performed under a Laboratory Independent Research grant (Work Unit ILIR HG31) titled "Metrics for Group Decision Making." This paper is one of a series growing out of a research project to examine small group performance with various types of electronic aids. These aids go by several names in the academic and trade literature: computer-supported cooperative work, electronic meeting systems, and groupware. The effective coordination and communication of information among distributed work groups is a growing need in many military contexts.

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1997	Final - Technical Paper

4. TITLE AND SUBTITLE
Information Sharing in Face-to-Face, Teleconferencing, and Electronic Chat Groups

5. FUNDING NUMBERS
C - N/A
PE - 61101F
PR - ILIR
TA - HG
WU - 31

6. AUTHOR(S)
Kenneth Graetz
Edward Boyle
Charles Kimble

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Dayton Research Institute
300 College Park
Dayton OH 45469

West Virginia University
Morgantown, WV 26506-6101

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Armstrong Laboratory
Logistics Research Division
Wright-Patterson Air Force Base, OH 45433-6503

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AL/HR-TP-1997-0044

11. SUPPLEMENTARY NOTES
Armstrong Laboratory Monitor: Edward Boyle, AL/HRGA, DSN 785-5169

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Experimental groups attempted to reach consensus on the rank ordering of three proposals for a fictionalized new weapon system. Each member of the four-person group received information on whether or not the three proposed systems met each of 10 desired criteria for the new system. Information was providde to the groups in the form of a "hidden profile." That is, some of the information was known to all group members, while other information was known only to individuals in the group. The groups haad to pool all relevant information, both common and unique, to reach a correct decision. The experimental variable was the meeting format: face to face, telephone conferencing, and electronic "chat" mode. As predicted, groups using the electronic "chat" mode made significantly fewer correct decisions, took more time to reach decisions, and experienced higher cognitive workload than the other two groups. Teleconferencing was the best communication mode for this information sharing problem. Collaboration technologies implemented in "groupware" formats need to consider information sharing and communication media as well as task type to maximize performance results, or to avoid undesirable group decision errors.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Information Sharing; Decision Making; Computer-Supported Cooperative Work; Groupware	42
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

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SUMMARY

Groups attempted to reach consensus on a simulated business problem. Each member of the 4-person group received information on whether proposed new systems from each of three companies met 10 desired selection criteria. The problem was cast in the form of a hidden profile in which information was provided either to all members of the group or to individual members uniquely. Groups had to correlate both common and unique information dispersed among the group members to make a correct decision. Experimental groups communicated using one of three formats: face-to-face, teleconference, and electronic chat. As predicted, group decisions were significantly better in the teleconferencing and face-to-face format rather than the chat format. Average decision time and cognitive workload were significantly greater in the electronic chat format than in the other two formats. Audio teleconferencing was the best communication medium for sharing information in this group collaboration problem.

INFORMATION SHARING IN FACE-TO-FACE, TELECONFERENCING, AND ELECTRONIC CHAT GROUPS

Compared to more traditional forms of group communication, electronic chat has a number of potentially limiting characteristics (McGrath & Hollingshead, 1993, 1994). Electronic chat has a relatively narrow bandwidth (Wellens, 1986) and a low level of media richness (Daft & Lengel, 1986; Trevino, Lengel, & Daft, 1987). Theoretically, communication channels with narrow bandwidths limit the rate of information flow, while wide bandwidth media allow increased information flow. Although similar to bandwidth, the concept of information richness is more qualitative. A media-rich communication has a greater potential for carrying information and conveying meaning. Presumably, rich media convey more information (e.g., emotional, attitudinal, and normative), in addition to the literal meaning of the communication, producing a more efficient and complete understanding of the message content. As a lean form of communication, electronic chat lacks the paralinguistic cues (e.g., voice pitch, loudness, rhythm, inflection, and hesitations) that other formats convey. Such cues may provide important information regarding the meaning of a message as well as the emotional state of the speaker. Research suggests that a substantial proportion of the meaning of a conversation is conveyed through paralinguistic cues (Birdwhistell, 1970) and that people form more accurate impressions of a speaker when such cues are conveyed (Chawla & Krauss, 1994). Research on the communication of emotion also emphasizes the importance of the paralinguistic channel, particularly for detecting negative affect (Apple & Hecht, 1982). Finally, paralinguistic information and nonverbal "leakage" may be particularly critical in the use or detection of deception (Ekman & Friesen, 1974).

A second limitation of electronic chat is that the production of speech acts is more laborious than for spoken conversations. It is easier to recite than to write a speech act. This may have several detrimental consequences for electronic chat. People engaged in electronic chat discussions may purposely omit statements normally offered during telephone or face-to-face (FTF) conversations. Likely candidates for omission are verbal back channels or brief utterances indicating agreement, attention, or understanding (Boyle, Anderson, & Newlands, 1994). Such statements, perhaps deemed too trivial to type, may be particularly important for collaborative activities requiring the formation of group consensus. In such tasks, verbal back channels may allow individuals to determine whether the group is mutually grounded (i.e., whether crucial information has been received and understood; Clark & Brennan, 1991).

A third limitation of electronic chat involves the coordination and integration of information. Unlike oral communication, chat tools allow group members to submit messages simultaneously. Straus (1996) argues that simultaneous participation may lead to "attention blocking," wherein members of electronic chat groups fail to attend to the messages of others while formulating and typing their own responses. As the size of the group increases, it may become more difficult to process the statements. Group members may experience problems identifying the source of the message, directing a response to a specific individual, associating others' responses with preceding statements, or monitoring the stream of statements for specific responses.

These limitations (i.e., low bandwidth, costly utterance production, and coordination difficulties) should be expected to reduce the effectiveness of groups engaged in collaborative tasks. Given the absence of paralinguistic cues, electronic chat groups may be at a disadvantage when engaging in tasks that require monitoring group members' emotions, detecting subtle meanings, using deceptive tactics, or validating information as truthful. Assuming that electronic chat groups tend to omit or reduce the number of verbal back channels as a means of minimizing the effort involved in typing utterances, they may have more difficulty reaching consensus than FTF or teleconferencing groups. Finally, coordination problems may become particularly acute in decision-making tasks requiring the exchange and integration of information. For example, in a relatively large group that includes a number of experts, all of whom have information necessary to solve a problem, any difficulties collecting, structuring, or integrating that information may elevate cognitive workload and increase the likelihood of errors.

This may present a problem in Computer-Mediated Communication (CMC) to facilitate team collaboration in synchronous (i.e., same time) but distributed (i.e., different places) conditions. One of the most common applications of CMC, both synchronous and asynchronous, is information sharing within cross-functional or expert groups. Many work groups include experts who bring specialized or unique knowledge to the collaborative task. In many modern organizations, effective collaboration requires rapid integration of group effort, often among team members who are geographically separated. Often, these groups must make decisions that require the communication and integration of unshared information.

Research suggests that unguided groups often fail to share relevant information experience and arrive at inferior or incorrect solutions. Laboratory groups engaged in information sharing tasks have demonstrated a tendency to focus their discussion on information known to all of the group members (i.e., shared information). Unique or unshared information, perhaps known to only one of the group members, is often not discussed or is given significantly less attention by the group. This tendency has been labeled the "common knowledge effect" (Gigone & Hastie, 1993; Stasser, Taylor, & Hannah, 1989) and appears to become more pronounced as group size increases (Stasser, et al., 1989), as information load increases (Stasser & Titus, 1987), and in information sharing tasks without demonstrably correct solutions (Stasser & Stewart, 1992).

A number of explanations for the common knowledge effect have been advanced. Based on the principles of information sampling, shared information may have a greater probability than unshared information for being encoded and recalled by individual group members (Stasser et al., 1989; Stasser & Titus, 1985). Gigone & Hastie offered a related explanation, suggesting that individuals may attach greater weight or importance to shared information, allowing it to factor more heavily into the final decision than unshared information. Finally, self-presentational or strategic concerns may contribute to group members' reluctance to contribute unshared information (Bonacich, 1987; Hackman & Morris, 1983). Given that information sharing tasks are commonplace, error prone, and increasingly supported by CMC tools, it seems reasonable to predict a relatively poor fit between electronic chat tools and information sharing tasks and a subsequently high number of decision-making errors (McGrath & Hollingshead, 1993).

On the other hand, electronic chat tools may provide a number of advantages over traditional FTF and telephone conversations, thereby facilitating information exchange. Compared to spoken statements, text-based messages are often composed and edited more carefully and received more quickly (McGrath & Hollingshead, 1993), thereby potentially increasing the quantity and quality of information contributed during an electronic chat discussion. Furthermore, the ability to enter messages simultaneously may reduce the deleterious effects of production blocking or the cognitive interference (e.g., generating counter-arguments, forgetting) experienced by group members while waiting their turn to speak. Research suggests that production blocking may affect the creative productivity of group members engaged in plan or idea generation tasks, possibly contributing to the relatively poor performance of brainstorming groups versus isolated individuals (Diehl & Stroebe, 1987). Although members of electronic chat groups are not isolated, they are not necessarily bound by the traditional rules of conversation and are often free to enter statements at any time. Thus, the statements of others may produce less interference in electronic chat groups than in FTF or teleconferencing groups.

Finally, the use of a chat tool may reduce the social anxiety experienced by some group members. Many individuals experience discomfort in the presence of others, often accompanied by social awkwardness, inhibition, and a tendency to avoid social contact (Bruch et al., 1989; Leary, 1983). Zajonc (1965) suggested that this negative affect might interfere with an individual's ability to perform complex tasks. Although not necessarily anonymous, the statements contributed by members of an electronic chat group are subject to less scrutiny than those offered during FTF or telephone conversations. Thus, normally reticent individuals may experience less evaluation apprehension and may contribute more frequently in electronic meetings than in FTF or teleconferencing groups. Heightened anxiety produced by a status differential within the group may also have less impact on individual performance when group members are using a chat tool versus communicating in a FTF meeting or teleconference. This suggests that electronic chat tools may be a good choice for facilitating information sharing tasks and should lead groups to reach better decisions than when conversing in FTF or teleconferencing contexts.

To date, much of the research on CMC in distributed groups has focused on asynchronous communication. E-mail, newsgroups, and electronic bulletin boards are all designed to support groups distributed across time as well as location. Although e-mail can support relatively synchronous conversations and another group member may be encountered while posting a message to an electronic newsgroup or bulletin board, chat tools differ in several important respects. First, chat tools are designed to support synchronous communication only, with user interfaces that allow participants to view others' statements on a common screen immediately as they are entered. Thus, a typical electronic chat conversation would appear as a steady stream of statements. This differs from asynchronous electronic communication, wherein the user interface is typically not designed to display messages in real time. Instead, these tools offer more sophisticated word processing and database functions to help the user compose and edit a message, send it to the appropriate location, and retrieve responses that have been posted by other users. The second and most important difference between electronic chat conversations and e-mail or other more asynchronous electronic discussions is the greater degree of social impact (Latane, 1981) that accompanies co-presence. Presumably, all members of an electronic chat group are aware of the simultaneous presence of other people. Among other things, co-presence may increase social anxiety, group cohesion, and entitativity (i.e., "groupness" or the perception of a collection of individuals as a group; Campbell, 1958). Due to the greater level of social impact, group members participating in electronic chat discussions could reasonably be expected to behave differently than in asynchronous electronic discussions. Thus, conclusions from research on asynchronous CMC may not generalize well to electronic chat communication.

Even so, a number of relatively consistent findings have emerged from the CMC literature. Numerous studies have found participants in electronic discussions to be more uninhibited than individuals engaged in FTF or telephone conversations. This includes the increased use of profanity and emotionally charged language ("flaming") as well as other nonconforming behaviors (Hiltz, et al., 1978; Seigel, Dubrovsky, Kiesler, & McGuire, 1986; Sproull & Kiesler, 1991; Lea & Spears, 1992; Walther, Anderson, & Park, 1994). This indicates that the lower level of social presence in electronic discussions may reduce social anxiety and inhibition.

Another fairly consistent finding involves the relative participation of individuals engaged in group activities. A number of studies have demonstrated that individual participation in collaborative tasks is more evenly distributed in meetings using CMC than in FTF contexts, indicating a leveling of the effects of individual differences in personality and status (Bikson & Eveland, 1990; Hiltz, Johnson, & Turoff, 1986; Kiesler, Seigel, & McGuire, 1984; McGuire, Kiesler, & Siegel, 1987; Weisband, 1992). Research on the effects of CMC on the absolute quality and quantity of individual participation in group tasks has yielded mixed results. Studies comparing the brainstorming performance of groups using CMC tools with unassisted nominal groups (i.e., the same number of isolated individuals) have found beneficial effects for computer support for relatively large groups (n = 12; Dennis & Valacich, 1993; Valacich, Dennis, & Connolly, 1994). Smaller groups do not appear to benefit from the reduced social presence and lower levels of production blocking afforded by CMC.

In the area of group decision making, Hiltz, et al. (1986) and Seigel, et al. (1986) obtained no significant differences in decision-making quality when comparing FTF discussions with CMC. In contrast, Gallupe, DeSanctis, and Dickson (1988) found that groups using CMC tools performed significantly better than unassisted groups on an experimental problem-solving task. Although much of this research supports the notion that electronic chat facilitates information exchange by reducing social anxiety and increasing individual participation, few studies have examined directly the effects of CMC on information sharing in distributed groups.

One notable exception is a recent study by Straus (1996). In this study, FTF groups and those using an electronic chat tool engaged in a popular consensus building task (Subarctic Survival Situation; Lafferty, 1973) that involved rank ordering a list of items. Unshared "clues" regarding the correct ranking of the list items were distributed within the group. Although a number of interesting findings emerged, Straus found no indication that electronic chat either facilitated the sharing of unique information or improved the quality of the group's decision.

Unfortunately, it is not clear why the groups in this study failed to share unique information. The consensus-building task used by Straus differed from other experimental information sharing tasks in that it did not include any shared or common information. In all conditions, clues were known to one and only one individual. Thus, any tendency for the group to focus on shared information could not be observed. In addition, it was possible for groups to achieve a high quality solution without sharing the unique information. Although Straus informed participants that their solution would be evaluated against an expert ranking, groups may have underestimated the importance of the clues, perceiving the consensus-building task as more judgmental than intellective.

Finally, Straus discussed the possibility that group members may have been weighting certain clues more heavily than others. Of most relevance to the current study is Straus' speculation that the use of electronic chat may have led to coordination problems and subsequent process losses within the groups. Although groups using the electronic chat tool took significantly longer to reach a decision and were significantly less satisfied with their group's decision-making process than were FTF groups, direct evidence for coordination problems in electronic chat groups was not presented.

The current study was designed to determine whether distributed groups, communicating using an electronic chat tool, would perform as well on an information sharing task as groups engaged in oral communication (i.e., either FTF or teleconferencing). It was hypothesized that, while FTF and teleconferencing formats share many of the same information transmission characteristics, the limitations imposed by the chat tool would interfere with the integrative processes necessary to solve the problem. Thus, teleconferencing and FTF groups were expected to outperform distributed chat groups.

In order to gain some insight into the specific causes of the hypothesized performance deficit, discussions were recorded and measures of cognitive workload and satisfaction were obtained. It was hypothesized that electronic chat groups would experience a greater level of cognitive or mental workload and would be generally less satisfied with the group's process and eventual decision than would groups in the FTF and teleconferencing formats. It was also hypothesized that chat groups would be more likely than FTF and teleconferencing groups to employ faulty decision-making strategies in attempting to reach a decision.

A secondary purpose of the current study was to assess the possible benefits and detriments of distributed versus FTF meeting formats for conducting information sharing tasks in groups. Due to their relative lack of flexibility and higher feedback latency, it was hypothesized that distributed sessions (i.e., both teleconferencing and chat) would last longer than FTF sessions. In contrast, given that they were isolated, participants in the distributed conditions (i.e., teleconferencing and electronic chat) were expected to report feeling more willing to contribute information than individuals in the FTF condition.

METHOD

Participants

One hundred and forty-eight individuals, 45 males and 103 females, participated in the study. Participants responded to recruitment flyers posted at various campus locations. Most participants were undergraduate students at the University of Dayton. They received $10 for their participation and were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992).

Communication Channel

The current study included one major independent variable: communication channel. Experimenters assigned groups randomly to one of three communication conditions: face-to-face (FTF), teleconferencing, and electronic chat. In the FTF condition, four participants in the same room communicated through normal speech. In the teleconferencing condition, four participants sat in private cubicles and communicated with other group members by telephone. The telephone system used an open line that allowed all four members to communicate simultaneously (i.e., a standard teleconferencing format). Experimenters audio-taped group discussions in both the FTF and telephone conditions.

In the electronic chat condition, four participants sat in private cubicles and communicated over a computer network. The four computers were connected using a Windows for Workgroups network operating system. The network software included a communication tool (Windows Chat) that allowed users to type and send messages to other group members. This tool divided each member's computer screen into four colored windows, one window per group member. The tool displayed the users' messages simultaneously. Message transmission was immediate; the communication tool displayed messages as users typed. All messages remained on the screen throughout the computer-mediated discussion, thereby allowing individuals to review previous messages. Each window scrolled down automatically as the number of messages increased. Thus, the most recent messages were always in view.

Hidden Profile Task

A hidden profile problem used in a previous group decision making study was adapted for this study (Boyle, Wolfe, & Kimble, 1997). Groups were told that they would be playing the role of purchasing executives for a fictitious Aerospace Force and would be reviewing three proposals for a new airborne intelligence gathering system. Each individual was instructed to read over the Request for Proposals (RFP) and a checklist of information taken from proposals submitted by three imaginary companies: Franklin Enterprises, Starlight Incorporated, and Cape Industries. In addition to the graphic shown in Figure 1, the RFP included the following general description of the desired system:

Currently, the Aerospace Force has the ability to place ground sensors inside enemy territory. The sensors have passive sonar beacons that detect the movements of tanks and other military equipment. They can be placed secretly over an area of about 50 square miles in a random pattern. What is needed is an air vehicle that can fly over the sensor field and gather sensor readings. The new system will be used to gather, process, and transmit information from behind enemy lines concerning the location and movements of enemy ground forces. This information will be used to plan tactical air strikes. The Aerospace Force will consider proposals for this new system. It should include two parts: an air vehicle and an on-board computer.

The RFP also included a set of 10 desired operational requirements or criteria. Three of the criteria pertained to the air vehicle. The vehicle was to: (1) fit on a 2-ton capacity truck, (2) sweep the entire ground sensor field in 30 minutes or less, and (3) be recovered and re-deployed within 90 minutes. The next four criteria dealt with the on-board computer. The computer was to: (4) process data at 100 million instructional sets per second (MIPS), (5) be no larger than 40 cubic inches, (6) be no heavier than 10 pounds, and (7) average at least 1000 operating hours between failures. Finally, (8) the air vehicle and computer should cost $7 million or less, (9) past performance and experience with the company should be positive, and (10) the company must have the manufacturing capacity to produce the system.

Each participant also received a checklist of criteria satisfied by each of the three proposals. Each checklist displayed the 10 criteria along with an indication that: the proposal met the criterion (indicated by a "Y"), or the proposal failed to meet the criterion (indicated by an "N"), or the criterion was not addressed by the proposal (indicated by a blank space).

To implement the hidden profile, each group member received a different checklist. It was necessary for the group members to combine the information on their individual checklists in order to reach the correct rank ordering. Table 1 shows an information map as seen by each subject. For example, Subject 1 (S1) saw two negative and two positive items for Starlight, one negative and five positive items for Franklin,

Table 1. Information Distribution in the Hidden Profile

	Starlight				Franklin				Cape			
Criterion	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Fits on 2-ton truck	N	N	N	N		N			Y			
Sweep sensor field in 30 minutes			Y				N		N	N		N
Recover/relaunch in 90 minutes	N	N	N	N				N	Y	Y		Y
Can process at 100 MIPS		Y			Y	Y	Y	Y	Y	Y		Y
Computer smaller than 40 cu. in.				Y	Y	Y	Y	Y	Y		Y	
Computer weighs less than 10 lbs.				Y	Y	Y	Y	Y	N	N	N	
Computer 1000 hours before failure		Y			Y	Y	Y	Y	N		N	N
Costs less than $7 million	Y				Y	Y	Y	Y				
Past performance OK	Y				N	N	N	N		Y	Y	Y
Manufacturing capacity exists			Y					N				Y
True Profile	8+/2-				5+/5-				6+/4-			

and three negative and four positive items for Cape. Based on its overall profile, the Starlight Incorporated proposal satisfied the most criteria and should have been selected first, followed by the Cape Industries and Franklin Enterprises proposals, respectively. This conclusion was not apparent given the individual checklists, however. Each group member received a checklist indicating that the Franklin Enterprises proposal satisfied five criteria and failed to satisfy four other criteria. For each group member, two criteria were left unspecified for the Franklin Enterprises proposal. The checklists indicated that the Cape Industries proposal met four criteria and failed to satisfy three criteria. Three of the criteria for the Cape Industries proposal were left unspecified for each group member. Finally, members' checklists specified that the Starlight Incorporated proposal satisfied two criteria and failed to satisfy two other criteria. For each group member, six criteria were left unspecified for the Starlight Incorporated proposal. Based on the number of criteria satisfied on the individual checklists, group members should have entered the group discussion with the impression that the Franklin Enterprises proposal was the most desirable, followed by the Cape Industries and the Starlight Incorporated proposals, respectively. Again, only if all of the information regarding the Starlight Incorporated proposal was shared would the groups have arrived at the correct rank ordering (i.e., Starlight, Cape, and Franklin, respectively).

Procedure

Upon responding to the recruitment flyer, individuals' names and phone numbers were added to a list of potential participants. Experimenters then contacted interested individuals by phone to schedule a session. To increase the likelihood that four participants would attend each session, six individuals, three males and three females, were scheduled. If more than four individuals arrived for a single session, the appropriate number of extra participants were identified randomly, paid $10, and dismissed. No attempt was made to control the resultant groups' gender composition. Thus, various mixed-gender groupings were possible. The study included 12, 14, and 11 groups in the face-to-face, teleconference, and electronic chat conditions, respectively. There were no systematic differences in the gender composition of the groups across the three conditions.

Experimenters escorted participants into either private cubicles (in the teleconference and electronic chat conditions) or a small conference room (in the face-to-face condition). After obtaining informed consent, participants were asked to complete a pre-experimental questionnaire that assessed their level of computer experience. Participants rated their current level of computer usage on a 5-point scale, where 1 = none, 2 = very infrequent, 3 = occasional, 4 = moderate, and 5 = heavy, as well as their level of comfort using a mouse using a scale ranging from 1 (not at all comfortable) to 9 (very comfortable). In addition, participants rated their level of experience using both Windows and Macintosh environments using a scale ranging from 1 (very little or none) to 9 (very extensive). Finally, participants gauged their computer keyboard typing skill using a scale ranging from 1 (very low level) to 9 (very high level).

Each individual had access to a small, notebook-style computer during the course of the study. In the face-to-face condition, four computers were positioned around the conference table. In the other two conditions, the computers were located in the participant's private cubicle. General instructions, as well as a specific description of the task, were displayed on each computer screen. The instructional materials were produced and displayed using Microsoft's Word for Windows resident on each machine. Group members had read-only access to three documents: a set of general instructions, the request for proposals (RFP), and a proposal checklist. The instructions document described how to use the mouse to scroll a page of text and to view other open documents. Participants in the electronic chat condition also received instruction on the use of the chat tool.

Group members then had 10 minutes for private study of the general instructions, the RFP, and their individual checklists. Groups then discussed the proposals for 15 minutes and attempted to reach a consensus regarding the proposal ranking. Groups notified an experimenter if they reached a decision before the 15 minute deadline. During this discussion, group members had access to their own checklist. They were instructed not to display the checklist to other group members. Participants were also told that all of the criteria were equally important and were instructed to avoid placing more weight on one criterion versus another. Participants were told that other group members' checklists may include information missing from their own checklist. They were also assured that there was no inconsistent information (i.e., if included on multiple checklists).

After reaching a decision, a post-experimental questionnaire was administered. This questionnaire included a measure of subjective mental workload as well as a number of items assessing each member's impression of the group. All participants were then debriefed, paid, and dismissed.

Dependent Variables

Proposal ranking. Groups' final proposal rankings were judged as either correct or incorrect. Again, the correct proposal ranking placed the Starlight Incorporated proposal first, followed by the Cape Industries and Franklin Enterprises proposals, respectively.

Time to decision. Experimenters timed the duration of each group's discussion from the time they left the experimental room to the time that one or more group members notified an experimenter that a decision had been reached. The time limit for group discussions was 15 minutes. If the group had not reached a decision before the 15 minute deadline, a 2 minute warning was given. No group took longer than 17 minutes to reach a decision.

Subjective mental workload. Participants completed an adapted version of the NASA Task Load Index (TLX; Hart & Staveland, 1988), a widely used measure of subjective mental workload. The version of the TLX used in the current study included five dimensions of workload: (1) the perceived level of mental and perceptual activity required by the task (mental demand), (2) the perceived degree of time pressure experienced during the task (temporal demand), (3) the degree to which participants believed that their group had accomplished its goal (performance), (4) participants' estimates of the level of effort they expended on the task, (5) and the degree to which participants became frustrated during the task. All five dimensions were measured using 20-point scales, ranging from 0 (low) to 19 (high). These ratings were then averaged across group members to obtain a workload score for the group on each of the five dimensions.

Impressions of the group. The post-experimental questionnaire included items designed to measure group member's impressions of their group as well as aspects of their own performance in the group. A number of the items were adapted from an existing questionnaire (Bernthal & Insko, 1993) measuring perceived group cohesiveness and aspects of groupthink, or the tendency for groups to ignore contradictory information, suppress dissent, and rally around even irrational decisions (Janis & Mann, 1977).

Responses were collected using a 9-point Likert-type scale ranging from 1 (strongly agree) to 9 (strongly disagree). The 11 items included in the questionnaire were as follows:

"My group did not take the task seriously."

"I was motivated to work on the task."

"If there were differences in opinion, the people in my group did not pay much attention to them."

"The people in my group expressed pretty much the same ideas."

"Overall, I feel that my group made high quality decisions."

"When my perceptions were not in agreement with what other members believed, I kept my views to myself."

"I did not feel pressure to conform to what the other group members believed."

"I believe that my group's discussion was of high quality."

"I believe that the perceptions made by other group members were accurate."

"My group considered a lot of alternatives."

"My group went back to previously rejected ideas to reevaluate them."

These ratings were averaged across group members to obtain scores for the group on each of the 11 items. The last item on the questionnaire asked group members whether or not they agreed with their group's final proposal ranking. If the respondent did not agree, he or she was asked to provide a preferred ranking.

Recorded discussions. Due to the unique characteristics of the electronic chat discussions (e.g., typing rather than talking, synchronous discussions), the fact that the chat discussions were captured on each computer individually rather than as an integrated stream of messages, and the presence of a clear qualitative difference between the strategies used by successful and unsuccessful groups, a formal content analysis and statistical comparison across communication conditions of discussion-derived variables was deemed unfeasible and unnecessary. The only variable coded from the discussion data was the apparent strategy used by the group to solve the hidden profile problem.

Two trained judges reviewed all discussions and assessed the strategy used by the group to integrate the individual checklist information. Judges categorized groups as using (a) an integrative tallying procedure, wherein each group member relayed the specific criteria met by each proposal according to his or her individual checklist and one or more group member(s) tallied the number of criteria met by each proposal or (b) a non-integrative tallying procedure, wherein individual group members reported, in turn, the total number of criteria satisfied by each proposal based on their individual checklists. It should be noted that, although the specific criteria met by each proposal varied, all four members received checklists with the same number of "Ys" and "Ns" for each proposal. In addition, the checklists were constructed such that, from an individual's perspective, the Franklin Enterprises proposal satisfied the most criteria. Thus, the use of a non-integrative tallying procedure would lead to an incorrect proposal ranking. Interrater agreement for the strategy employed was 100 percent.

Unit of Analysis

Because the experimental task involved interaction among group members, the units of analysis was the group performance. We analyzed performances of 12, 14, and 11 groups in the face-to-face, teleconference, and electronic chat conditions, respectively.

RESULTS

Computer Experience

Across all participants, the average level of computer usage was 3.30 (SD = .46), indicating "occasional" usage overall. The average mouse comfort level was 7.52 (SD = .99) and participants reported greater exposure to Windows versus Macintosh operating systems (M = 5.55 and 3.56, respectively. SD = 1.56 and 1.30, respectively). Finally, participants' keyboard skill estimates averaged 5.82 (SD = .92). A one-way multivariate analysis of variance (MANOVA), using communication condition as the independent variable and the five computer experience measures as dependent variables revealed no significant communication effect, $F(10, 62) = 1.36$, ns. Computer experience did not vary systematically across communication conditions.

Proposal Ranking

The proportion of groups that arrived at the correct ranking for each communication condition is listed in Table 2. Thirty of the 37 teams correctly ranked the three proposals, Chi square (1) = 14.30, $p < 0.001$. A Kruskal-Wallis analysis of variance (ANOVA) revealed that accuracy varied significantly across communication conditions, X^2 (2) = 12.89, $p < .01$. Separate Wilcoxon rank-sum tests showed significant differences in accuracy between teams in the electronic chat and FTF conditions, Ws = 101.5, $p < 0.05$, and between teams in the electronic chat and teleconferencing conditions, Ws = 101.0, $p < 0.05$. Teams in the electronic chat communication condition were significantly less accurate than groups in the FTF and teleconferencing conditions, with no significant difference between groups in the teleconferencing and FTF conditions.

Table 2. Proportion of Accurate Rankings and Average Time to Decision

	Communciation Condition		
Variable	Face to Face	Telephone	Electronic
Number of Groups	12	14	11
Proportion Correct	0.92	1.00	0.45
Time to Decision (m)	6.08	4.62	13.78

Time to Decision. The time to decision, averaged across all groups, was 7.82 minutes (SD = 5.30). The fastest group finished the task in 1.67 minutes; the slowest group took 16.58 minutes to reach a decision (both groups reached the correct decision). Mean time to decision for groups in each communication condition is also listed in Table 2. A one-way ANOVA, using communication condition as the independent variable and time to decision as the dependent measure, showed a significant communication effect, $F(2, 34) = 22.03$, $p < 0 .05$. Post hoc, paired comparisons using a Bonferroni correction ($p = 0.05$) revealed that teams in the electronic chat condition took significantly more time to reach a decision than teams in both the FTF and teleconferencing conditions. No significant difference in decision time occurred between the teleconferencing and FTF conditions.

Subjective Mental Workload

The average ratings on each dimension of the TLX for groups in each communication condition are listed in Table 3. A one-way MANOVA, using communication condition as the independent variable and the five TLX measures as dependent variables obtained a significant communication effect, $F(10, 62) = 3.88$, $p < 0.001$. Separate ANOVAs revealed significant communication effects for four of the five TLX dimensions: mental demand [$F(2, 34) = 7.02$, $p < 0.01$], temporal demand [$F(2, 34) = 18.57$, $p < 0.001$], effort [$F(2, 34) = 21.56$, $p < 0.001$], and frustration [$F(2, 34) = 6.44$, $p < 0.01$].

Table 3. Average Ratings on Five Dimensions of Subjective Mental Workload

	Communication Condition		
Workload Measure	Face to Face	Telephone	Electronic
Mental Demand*	8.14	8.41	12.32
Temporal Demand*	5.17	3.25	9.48
Performance*	16.69	17.75	16.11
Effort*	6.56	6.38	11.59
Frustration*	4.52	3.78	7.00

Note. Response range from 0 (Low) to 19 (High).

* Items with significant communication differences ($p < 0.05$

Post hoc, paired comparisons using a Bonferroni correction ($p = 0.05$) revealed that, for all four dimensions, groups in the electronic chat condition experienced significantly higher mental workload levels than groups in the other two conditions. Groups in the electronic chat condition reported experiencing significantly greater amounts of mental and temporal demand, exerting significantly more effort, and feeling significantly higher levels of frustration than groups in either the teleconferencing or the FTF condition. No significant differences were obtained between the FTF and teleconferencing conditions on any of these TLX dimensions.

Impressions of the Group

A one-way MANOVA, using communication condition as the independent variable and the 11 post experimental items as dependent variables, obtained a significant communication effect, $F(22, 50) = 1.77$, $p. < 0.05$. Separate ANOVAs revealed significant communication effects on 4 of the 11 items: "I was motivated to work on the task" [$F(2, 34) = 4.74$, $p < 0.05$], "The people in my group expressed pretty much the same ideas" [$F(2, 34) = 3.62$, $p < 0.05$], "When my perceptions were not in agreement with what other members believed, I kept my views to myself" [$F(2, 34) = 4.36$, $p < 0.05$], and "I believe that the perceptions of other group members were accurate" [$F(2, 34) = 3.44$, $p < 0.05$].

Post hoc, paired comparisons using a Bonferroni correction ($p. = 0.05$) revealed that groups in the FTF condition reported significantly higher levels of task motivation than groups in the other two communication conditions. No significant difference was observed between the teleconferencing and electronic chat conditions. On the item pertaining to people in the group expressing the same ideas, a trend analysis indicated a significant linear trend, $F(1, 34) = 7.23$, $p < 0.05$, with electronic chat groups indicating the lowest level of agreement with this item and teleconferencing groups exhibiting the highest level agreement. A linear trend was also obtained for the item pertaining to keeping one's views private, $F(1, 34) = 8.70$, $p < 0.01$. Groups in the electronic chat condition expressed the most agreement with this item, while groups in the teleconferencing condition expressed the least agreement. Finally, another significant linear trend was observed on the questionnaire item pertaining to the accuracy of other members' perceptions, $F(1, 34) = 6.78$, $p < 0.05$. Groups in the electronic chat condition reported the highest level of disagreement with this item (i.e., indicated the lowest level of perceived accuracy), while groups in the teleconferencing condition expressed the lowest level of disagreement (i.e., indicated the highest level of perceived accuracy).

Agreement With Group's Decision

The final item on the post experimental questionnaire asked individual group members whether or not they agreed with their group's final proposal ranking. All 148 individuals in the study reported agreeing with their group's final decision.

Recorded Discussions

During the transcription and compilation of the group discussions, a very clear difference emerged between the strategies used by successful and unsuccessful groups. All of the groups that arrived at the correct proposal ranking used an integrative tallying procedure. Of the seven groups that failed to reach a correct decision, three used a non-integrative tallying procedure. The remaining four groups, all within the electronic chat condition, attempted to use an integrative tallying procedure. Although apparently cognizant of the necessary procedure, these four groups appeared unable to integrate the checklist information effectively in the computer-based discussion format. In all four cases, individual group members attempted to structure the information on the screen in the form of a grid or table. Two of the four, groups made at least two attempts to integrate and display the data on the screen, utilizing different tabular structures. Table 5 lists the typed statements of one group member engaged in an electronic chat discussion. As can be seen in Statements 12 to 19, this individual was attempting to construct a form or matrix to store the information being collected from the group.

DISCUSSION

Groups in the current study attempted to reach consensus on the rank ordering of three proposals for a new airborne reconnaissance system. Each member of the 4-person group received information regarding whether or not the proposed systems met each of 10 desired criteria. Forming a hidden profile problem (Stasser et al., 1989; Stasser & Titus, 1985), individual checklists included unique as well as common information. Groups could solve the problem and arrive at the correct proposal ranking only by sharing unique information known to individual group members. This study expanded upon existing research in the area of CMC and information sharing (Straus, 1996) in that it used a task with a demonstrably correct solution that could only be achieved through the sharing of unique or unshared information. The current study also included procedures designed to promote the equal weighting of criteria as well as a teleconferencing condition to determine whether the elimination of visual access was sufficient to disrupt information sharing processes. We expected that coordination difficulties would severely limit the ability of groups in the electronic chat condition to integrate information, leading to the use of faulty decision-making strategies and an eventual, sub-optimal solution. We also expected that electronic chat groups would experience a greater level of cognitive or mental workload and would be generally less satisfied with the group's process and eventual decision than would groups in the FTF and teleconferencing formats.

Given that individual group members could access their checklists at any point during the group discussion and were aware of the possibility of unique information, selecting the correct proposal ranking should have been a straightforward matter. Indeed, most groups (81.1%) ranked the proposals in the correct order, finding the Starlight Incorporated proposal the most desirable, followed by the Cape Industries and Franklin Enterprises proposals, respectively. Thus, most groups were able to share information effectively and overcome the initial, misleading perception that the Franklin Enterprises proposal satisfied the most criteria. Most of the groups (>90%), including those in the electronic chat condition, went about evaluating the proposals in a consistent and rational manner. Using an integrative tallying procedure, group members were called upon to relay the specific information from their individual checklists. The information was then tallied, typically by one member of the group, and the number of criteria satisfied by each proposal was established. Only three groups failed to use this strategy and all three subsequently failed to rank the proposals correctly.

As predicted, however, groups in the electronic chat condition apparently experienced greater difficulty solving the hidden profile task than groups in the teleconferencing and FTF conditions. Over half of the groups in the chat condition failed to reach the correct decision, favoring instead the preference ranking suggested by their individual checklists. Average decision time was also significantly longer in the electronic chat condition than in both of the other two formats. In addition, compared to the other communication formats, chat groups reported experiencing significantly greater levels of frustration as well as mental and temporal demand. Chat groups also perceived themselves to be exerting significantly more effort during the task than FTF and teleconferencing groups. Thus, performance deficits on the information sharing task only appeared when distributed groups interacted using the synchronous, electronic channel provided by the chat application.

These findings suggest a mismatch between the communication channel and the group task. An analysis of the recorded group discussions revealed that, although most of the groups in the electronic chat condition selected an integrative tallying procedure (an effective strategy that would likely have resulted in the successful solution of the problem) they appeared to experience difficulties coordinating member inputs and verifying information. This slowed their progress and heightened their level of frustration and mental effort. The use of repetition and verbal back channels to rapidly verify information presumably allowed groups communicating orally to integrate their checklists without the help of some formal structure (i.e., a group spreadsheet or data matrix). A review of the group discussions revealed that a large proportion of the statements in the FTF and teleconferencing discussions were either requests for verification or direct responses to such requests (M = 0.30 and 0.32, respectively). Using pairwise comparisons and a Bonferroni correction (p. = 0.05), the proportion of such statements in the electronic chat condition (M = 0.19) was found to be significantly smaller than in both of the other two communication conditions. No significant difference was obtained between FTF and teleconferencing groups.

Further evidence that groups in the electronic chat condition lacked the ability to coordinate member inputs was found when examining some of the chat discussions. A number of groups attempted to construct a matrix or data structure within the confines of the electronic chat environment. What appeared to be lacking in this group represented in Table 5, as well as in other electronic chat groups that attempted similar forms of record keeping, was a clearly-defined and consensual procedure (e.g., turn-taking) for populating the database with information from individual checklists. Also, in the current electronic chat system, it was impossible for group members to edit existing statements. Thus, group members attempting to fill data structures did so by gleaning information from previous statements. Furthermore, once entered, it was impossible for individuals to change or update the information in the form. In all cases, including the group represented in Table 5, attempts to construct and utilize effectively these data structures in electronic chat environments failed to improve the group's decision. Again, this provides evidence that, although they understood clearly the process required to solve the problem, electronic chat groups experienced difficulty collecting and processing expert information.

Possibly as a result of the increased level of cognitive effort and frustration, groups in the electronic chat condition perceived more disagreement within the group and expressed greater doubt regarding the accuracy of others' information than did groups in the FTF and teleconferencing conditions. Members of electronic chat groups also reportedly kept their ideas private to a greater degree than members of other groups. This is surprising given that previous research has demonstrated less inhibition in CMC versus other communication formats (Hiltz, et al., 1978; Seigel, Dubrovsky, Kiesler, & McGuire, 1986; Sproull & Kiesler, 1991; Lea & Spears, 1992; Walther, Anderson, & Park, 1994). It is difficult to interpret this finding, however, given the wording used in the question. The term "views" could have referred to members' opinions and beliefs as well as their checklist information. Thus, this finding does not necessarily reflect reluctance on the part of group members to contribute checklist information. Instead, it may refer to a disinclination to engage in lengthy discussions using the electronic chat tool.

The relative success of teleconferencing as a medium for information exchange was surprising. Not only did teleconferencing groups perform as well on the information sharing task as FTF groups, but, contrary to prediction, teleconferencing groups arrived at a decision just as quickly as FTF groups. In addition, individuals in the teleconferencing condition appeared to have a more positive impression of their group relative to participants in the FTF and electronic chat conditions. This was reflected in reports of greater homogeneity, openness, and accuracy by teleconferencing groups versus FTF and electronic chat groups. It appears that teleconferencing may be an effective replacement for FTF discussions when attempting to share information in a distributed group.

Two potential limitations of the current study merit discussion. First, the current task was designed to highlight difficulties involved in integrating information. It was not intended to test individuals' cognitive or interpersonal skills or to tap into a widely shared information base. The task was fairly straightforward and pseudo-technical, involving information with which many participants were unfamiliar. Although these characteristics might be expected to promote low motivation and confusion, participants in the current study showed no signs of either. Most groups understood quickly how to solve the problem and went about it with some enthusiasm. Further, the use of unfamiliar material may have prevented participants from weighting unequally specific pieces of information, a problem that has plagued other information sharing studies (Straus, 1996). Obviously, these findings should only be generalized to collaborative tasks of the variety used in the current study. Future research might focus on the application of CMC in judgmental or problem solving tasks without objectively correct solutions. Such studies may expose other limitations of CMC and further define the potential applications for this new form of communication.

A second limitation of the current study is that it only used 4-person groups. Clearly, the effectiveness of CMC depends not only on the nature of the task, but on the size of the group. The effectiveness of electronic chat, for example, probably varies inversely with group size. Electronic chat between two or three individuals may be fairly easy to orchestrate and just as effective as teleconferencing for mediating information sharing in expert groups. As group size increases, however, this form of communication may become unwieldy. Further research on the interaction between group size, task type, and communication modality is necessary to establish firm recommendations on the use of CMC for facilitating distributed group work.

It could be argued that participants in the electronic chat condition would have adapted to the medium over time and that the current findings are simply an artifact of the software and methods used. Indeed, research suggests the impact of CMC lessens as users become more experienced (Hollingshead, McGrath & O'Connor, 1993; Kraut, Galagher, Fish, & Chalfonte, 1992). It should be noted, however, that participants in the current study were relatively experienced computer users and exhibited no general difficulties learning about or using the chat tool. Further, participants reported feeling fairly comfortable using a mouse and keyboard. It seems unlikely that the results of this study were caused by participants' initial lack of familiarity with the chat tool. Instead, they reflect a more fundamental task-technology mismatch. Although new conventions for communicating meaning and reaching consensus may evolve in this medium (c.f., emoticons; Raymond, 1981), electronic chat does not appear to be well suited for sharing information in distributed, expert groups.

Despite their potential limitations, it is not surprising that electronic chat tools are featured in many new groupware products (e.g., Microsoft NetMeeting, White Pine Enhanced CU See Me). Text-based messaging is a fast and reliable communication medium. Hidden costs may be overlooked, however, in an organization's rush to remain on the cutting edge. Tools that may be very effective for supporting some group tasks may be ineffective for supporting others, and, in some cases, may actually reduce group effectiveness. Regarding information sharing in expert groups, the current study suggests that, although electronic chat groups approach information sharing in an efficient and rational manner, the communication medium limits the group's ability to coordinate and verify information. Consequently, when unshared or unique information is essential to solving the problem, FTF and teleconferencing groups may outperform electronic chat groups.

When combined with other forms of support, however, electronic chat tools may provide a cost effective and satisfying alternative to FTF or teleconferencing meetings. In the current study, groups in the electronic chat condition would have obviously benefited from a shared workspace that included an interactive spreadsheet or other data structure capable of storing and displaying the combined information from members' checklists. In fact, several groups attempted to create such structures during the course of their electronic discussions. Thus, future research should focus on the effectiveness of groupware that combines text-based messaging with collaborative tools designed to store, organize, and process information. It should also examine the effects of desk top video, which replicates many of the features of FTF communication and represents an important new dimension of collaboration science and commerce.

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