An Exploratory Comparison of Four Modes of Communication for Determining Requirements: Results on Creativity, Quality and Satisfaction

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Abstract

Previous research has indicated that groups can benefit from the combination of face-to-face and asynchronous computer-mediated communication for conducting work. This exploratory experiment compares the effectiveness of four different modes of communication for groups working on the upstream phases of software development: (1) face-to-face (2) synchronous computer conferencing (3) asynchronous computer conferencing (4) combined -- FtF and asynchronous computer conferencing. Teams of graduate students determined the requirements for an automated post office as a course assignment, over a two-week time period. The creativity and quality of solutions produced by groups in the combined condition were higher than those of the remaining three communication modes. Combined groups were generally more satisfied with their solutions, although no differences among conditions were found regarding satisfaction with the process used to accomplish work.

1. Introduction

Increased competitive pressures necessitate that today's software developers produce innovative, creative software solutions to corporate problems, in ever-shorter development cycles (14, 3, 10). The early stages of software development are perhaps the most important in terms of meeting these demands (6, 4, 23) as it is here that developers determine the requirements for the software, and thus 'figure out what to build' (15). Decisions made during these early stages impact the remainder of the software development project and impose critical limitations on the ease of later software modification.

Importance of communication: Upstream development stages are essentially a process of communication (15) where knowledge acquisition, knowledge sharing, and knowledge integration must be accomplished (24). These information intensive and time-consuming activities cut across functional business units and organizational boundaries, requiring different parties (e.g. users and software engineers) to develop a mutually shared understanding of problems and the impact of technical solutions.

Indeed, when summarizing the results of a recent survey within one large software development company, Kraut and Streeter (17, p. 80) comment, "The challenge in software engineering should not be to devise methods to minimize personal communications, for example, as formal specification languages are intended to do. Rather a goal should be to make interpersonal communication more efficient and effective..." These researchers suggest that computerized tools that facilitate distributed meetings, such as computer conferencing (13), are "likely to be useful, by opening up the meetings, making them more efficient, and providing an archive"(17, p. 80).

In fact, organizations are beginning to embrace technology to enhance collaborative group work. For example, some software development teams work using a combination of both face-to-face meetings and computer-mediated communication (e.g. 16). Similarly, Cutosky et al. (5) describe the use of a mix of collaboration modes (e.g. face-to-face and distributed, synchronous and asynchronous) and technologies (mostly Web-based software tools) that enabled engineering teams to be composed of highly skilled specialists from different organizations and different locations. Through the use of a combination of various collaborative modes and tools, the dispersed teams were able to design and prototype a complex device (i.e., an optical seeker used in missiles) in an unprecedented six months.

Given these realities, there is an increasing need to conduct research that reflects the new forms and means that organizations are employing to accomplish complex work (e.g., 18, 16). To date, the vast majority of GSS research has focused on groups using a single medium (i.e., either synchronous GSS or asynchronous GSS). Moreover, an extensive literature search revealed that

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with over 140 experiments studying group support systems and computer-mediated communication, only three studies (8, 12, 7) investigated the usefulness of combining computer-mediated communication with other communication media (i.e. face-to-face, telephone) over a period of time, as groups proceed through the completion of complex projects. (9).

With the intent of addressing this gap in the GSS research, this paper presents results of an exploratory experiment comparing the effectiveness of groups using various forms of media to conduct problem solving activities over a period of time. The experiment focuses on comparing groups who use a combination of both face-to-face and asynchronous computer conferencing communication modes to groups using a single communication mode of either face-to-face, asynchronous computer conferencing, or synchronous computer conferencing.

2. Background

2.1 Phases of work and communication modes

The content of group work differs over the life of the group's problem solving activity. For example, Chidambaram and Bostrom (2) characterize early group work where group members spend time getting acquainted with one another and work to establish group goals, outline tasks to be accomplished, set priorities, and define member roles. Group work during these early stages does not center around the extensive sharing of information and documents, but rather the focus of the group is on planning their work (11). After the initial phase, groups often enter an execution phase, where members work individually and then share information and their accomplishments with their group members (11). During the final phases of group work, groups strive to integrate the work of individual members in order to complete their tasks and prepare materials for external review.

Compared to computer-mediated communication, Kiesler and Sproull (16) theorize that face-to-face meetings are a more effective means for defining issues, securing commitment, and decomposing the task -- all activities occurring during the initial phase of group work. However, during the middle (execution) phase of group work, groups need to share information quickly and frequently. Kiesler and Sproull (16) speculate that groups can benefit from mechanisms that allow for the quick and frequent transmission of information in a form that will permit other members to interpret and use it. Indeed, participants in both the Eveland and Bikson (7) study and Galegher & Kraut (12) study found computer-mediated communication to be effective for sharing information. Finally, groups who are in the late stages working to complete their task may find face-to-face communication more effective.

2.2 Summary of initial study

In a previously published study, we reported on research comparing the effectiveness of groups using different modes of communication (face-to-face versus distributed asynchronous via computer conferencing) and different problem solving approaches (structured vs. unstructured) (20, 21). All groups worked for two weeks developing the requirements and high-level design for an automated post office. We were particularly interested in the impact that asynchronous computer conferencing (asynchronous-CC) had on requirements determination in terms of the creativity and quality of group solutions and also the satisfaction of groups using this medium. It was found that the quality of solutions produced by the asynchronous-CC groups was judged to be marginally higher than that of the FtF groups. However, the creativity of solutions produced by the computer conferencing groups was judged to be significantly higher than FtF groups. Problem solving approach did not significantly impact creativity or quality. Both asynchronous-CC and FtF groups were equally satisfied with their solutions; however FtF groups were marginally more satisfied with the process they used in reaching their solutions.

3. Research Framework, Experimental Design and Hypotheses

Building on our previous research, the current study expands the exploration of the effectiveness of various modes of communication for groups working on the upstream portions of software development. The primary research question investigated in this experiment is: Are groups that use a combination of both face-to-face and computer-mediated communication more effective than groups that use a single mode of communication?

Four communication conditions are explored in this experiment: (1) Face-to-Face (FtF), (2) distributed asynchronous computer conferencing (asynchronous-CC), (3) co-located synchronous computer conferencing (synchronous-CC) and (4) combined communication - a sequence of FtF, asynchronous-CC and FtF (combined). Both the asynchronous-CC and synchronous-CC groups communicated using only a computer conferencing system, however the asynchronous-CC groups were distributed in space and time, while the synchronous-CC

groups worked simultaneously within the same room. The FtF groups met twice and group members had no communication with one another between meetings.

Literature on phases of group work (2, 16) indicates that groups in the initial phase of work focus on planning the work of the group, groups in the execution phase of work need to share information and documents among members, while groups in the final phase need to integrate the work of group members. Therefore, we designed the fourth communication mode (combined) to address these differing needs of groups. The combined groups had an initial face-to-face meeting (initial phase), followed by a period where all communication occurred using a computer conferencing system (execution phase), followed by a final face-to-face meeting (final phase). Thus, this treatment combined aspects of both the FtF treatment and the asynchronous-CC treatment. The experiment ran for a period of two weeks.

3.1 Hypotheses on Creativity, Quality and Satisfaction

Based on results from our initial study and drawing on research comparing groups using a combined communication mode, we present the following hypotheses on creativity of solution, quality of solution, and satisfaction.

Creativity: Based on the findings of the few studies which allowed groups to combine face-to-face and computer-mediated modes of communication over a period of time, we speculate that groups in the combined condition will exhibit higher amounts of creativity than groups in the remaining communication modes. We surmise that the combined groups will be better able to plan and organize their work and thus experience an improved start compared to the asynchronous-CC and synchronous-CC groups. Also, the combined groups will have the benefit of continued communication over the two week time period of the experiment, whereas the FtF groups and the synchronous-CC groups can only communicate during the scheduled meeting times. Thus, we hypothesize that:

1.1 Combined groups will produce more creative solutions than asynchronous -CC groups.

1.2 Combined groups will produce more creative solutions than the synchronous-CC groups.

1.3 Combined groups will produce more creative solutions than FtF groups.

The major finding of our initial study was that distributed asynchronous computer conferencing groups developed significantly more creative requirements definitions, compared to unsupported face-to-face groups. However, due to a lack of comparison to synchronous computer-mediated communication, it was indeterminable whether the increased amounts of creativity were in fact due to the technology being used in a distributed asynchronous manner. The question that could not be answered was whether the technology, in general, was the determining factor of the increased amounts of creativity, or whether it was the interplay of computer-mediated communication over time and from a distance. Therefore, in the current experiment, we incorporate a synchronous computer conferencing treatment so as to isolate the factors of time and distance from the use of technology.

Research on minority influence theory (e.g. 19) and group creativity/innovation (e.g. 25) (see 21 for a detailed explanation) indicates that creativity is enhanced when groups are not constrained by time. Similarly, communication among group members is believed to be important for encouraging creativity. Therefore, due to the increased ability for the asynchronous-CC groups to stay connected with group members and the relative lack of time pressures compared to both the synchronous-CC and FtF groups, and based on the results from our first experiment, we hypothesize that:

1.4 Asynchronous-CC groups will produce more creative solutions than synchronous-CC groups.

1.5 Asynchronous-CC groups will produce more creative solutions than FtF groups.

Quality: According to minority influence theory (Nemeth, 1986), groups exhibiting higher amounts of creativity will produce outcomes of higher quality. However, results from our first experiment showed that, although the asynchronous-CC groups were judged to be significantly more creative than FtF groups, the quality of asynchronous-CC groups' ideas was only marginally better than FtF groups. Perhaps this finding is attributable to the need for some face-to-face communication. The literature reviewed on phases of group work indicates that computer-mediated groups striving to reach consensus or commitment may benefit from face-to-face communication at the onset and conclusion of their work. Therefore, we speculate that the groups in the combined mode will produce solutions of higher quality than groups in the remaining communication modes. Thus, we hypothesize that:

2.1 The solution quality of the combined groups will be of higher quality than the asynchronous-CC groups.

2.2 The solution quality of the combined groups will be of higher quality than the synchronous-CC groups.

2.3 The solution quality of the combined groups will be of higher quality than the FtF groups.

Neither the FtF nor the synchronous-CC groups have the benefit of continued communication over time, as do

Table 1 Experimental Design

Experimental Condition	Number of Groups	Training	Meeting 1	14 Day Interval	Meeting 2
Synch-CC	12	yes	yes	no interaction	yes
FtF	10	yes	yes	no interaction	yes
Asynch-CC	10	yes	no	asynchronous communication	no
Combined	10	yes	yes	asynchronous communication	yes

the asynchronous-CC groups. Based on our expectation that the FtF and synchronous-CC groups will be significantly less creative than asynchronous-CC groups, we expect that the FtF and synchronous-CC groups will also exhibit a lower level of quality, compared to asynchronous-CC groups. Therefore, we hypothesize:

2.4 Asynchronous-CC groups will produce solutions of higher quality than synchronous-CC groups.

2.5 Asynchronous-CC groups will produce solutions of higher quality than FtF groups.

Solution Satisfaction: Solution satisfaction pertains to groups' satisfaction with the outcome that they produced. In our initial study, no significant difference was found between the level of solution satisfaction between asynchronous-CC and FtF groups. With the inclusion of the combined treatment in the current experiment, we speculate that the combined groups, given the ability to work on their solutions both asynchronously and in a final FtF session, will be more satisfied with their end-product than groups in the other treatments. Therefore, we hypothesize that:

3.1 Solution satisfaction of the combined groups will be higher than that of asynchronous-CC groups.

3.2 Solution satisfaction of the combined groups will be higher than that of synchronous-CC groups.

3.3 Solution satisfaction of the combined groups will be higher than that of FtF groups.

Process Satisfaction: Process satisfaction is a measure of the satisfaction experienced by groups regarding the method(s) used to accomplish work. Thus, each different mode of communication represents a different process for accomplishing work. In the first experiment, FtF groups were marginally more satisfied with the (face-to-face) process compared to the distributed asynchronous computer-mediated groups. Based on the literature regarding the phases of group work, we expect that the combined treatment will have the best fit in terms of the varying needs of groups as they go through the initial, execution, and final phases of work. Thus, we hypothesize that:

4.1 Process satisfaction of the combined groups will be higher than that of asynchronous-CC groups.

4.2 Process satisfaction of the combined groups will be higher than that of synchronous-CC groups.

4.3 Process satisfaction of the combined groups will be higher than that of FtF groups.

4. Method

Design: This experiment can best be described as an example of a "patched up" design. The asynchronous-CC groups and the FtF groups are the same groups that were included in our initial study (20, 21). These two conditions were "run" during the time period from Fall 1993 through Fall 1994. Groups in the synchronous-CC and combined conditions were not included in any prior study. These conditions were carried out from Fall 1994 through Fall 1995.

Since the problem solving approach made "no difference" in our first study, it was decided not to fill in a complete 4 x 2 design. Though the same task, procedures, system, and type and source of subjects were used for all conditions, the fact that groups were not randomly assigned to all of the conditions during the same time period raises some methodological limitations that will be explored in section 5.1.

There are a total of 42 groups included in this study (see Table 1). All groups met face-to-face for training. When working on the actual experimental task, groups in the synchronous, combined, and FtF conditions met twice for two face-to-face sessions, occurring exactly two weeks apart. Groups in the asynchronous condition conducted all work using the conferencing system over a two-week time period.

Task: The Automated Post Office (APO) is the task used in this experiment. Groups were required to reach

consensus on the initial requirements of the APO and to submit these requirements in a formal report at the end of the experiment; each group produced a single report. The report was to cover the functionality of the APO along with implementation considerations and was also to contain a description of the user interface design. This is a modification of the same task used by Olson et al. (22), with an added emphasis on the design of the user interface. Olson et al. characterize this task as incorporating Planning, Creativity, Decision-Making, and Cognitive Conflict (22).

Subjects: Subjects consisted of graduate students in the CIS and IS majors at the New Jersey Institute of Technology (NJIT) and MBA students from Rutgers University. For their participation, all subjects received course credit. The majority of subjects had coursework and/or job experience directly relevant to systems design. Group size ranged from 4 to 7 persons for all groups. Subjects were scheduled to meet based on availability for scheduled sessions.

Technology and Facilitation: All of the computer-mediated groups (synchronous-CC, asynchronous-CC, and combined) communicated using the EIES 2 computer conferencing system developed at NJIT. Each computer-mediated group communicated in its own conference set up on EIES 2. The conferences were minimally facilitated. The conference facilitator's role was that of a technical assistant, helping groups with equipment problems and answering questions of a technical nature.

Training: All groups met face-to-face for training and used the same practice problem, called Entertainment for Dutch Visitors (22). Groups using the computer-conferencing system were trained on the communication features of EIES 2 and worked on the conferencing system using the practice problem. FtF groups also worked on the practice problem, without using technology. Groups in the combined condition received the same training as did the CC-synchronous and CC-asynchronous groups. All training sessions were completed within 1 1/2 hours.

Procedures: After training, groups in the FtF and combined conditions remained for one additional hour to begin work on the APO task. This meeting constituted the first face-to-face session for these groups. At the end of the two-week time period, these groups reconvened for a second face-to-face meeting, which lasted up to 2-1/2 hours. These groups were provided with a computer with word processing software for their second meeting. In the interim between session one and two, group members in the FtF condition were permitted to work independently on the APO; however, they were instructed not to communicate with fellow group members during this time.

Groups in the combined condition communicated asynchronously using the computer conferencing system during the two week interim between the two face-to-face sessions. For the second face-to-face meeting, groups in the combined condition were provided with a computer with word processing software and a terminal to connect to EIES. The groups were instructed that they had 2-1/2 hours to complete the task.

After the training session, synchronous-CC groups remained for their first synchronous meeting which lasted up to two hours. The synchronous-CC groups were required to conduct all of their work using the computer conferencing system; as in the asynchronous condition, these groups were not permitted to talk, or otherwise interact with one another, other than by using the conferencing system. Similar to the FtF groups, these groups were instructed not to communicate with each other regarding any aspect of the APO task between session one and session two. Two weeks after their first meeting, the synchronous-CC groups reconvened for a second meeting which lasted up to 2-1/2 hours. Based on pilot studies, groups in the synchronous-CC condition were given a full hour longer (in the second meeting) to work together than were groups in the FtF and combined conditions, in order to compensate for the slowness in typing.

All groups had a leader who volunteered for the role at the end of the training session, sometimes with encouragement from the facilitator. Each leader was responsible for ensuring that his/her group submitted a formal report at the end of the two-week experimental time period.

For each FtF group, the facilitator completed an observation form at the end of the second session, rating the group on such aspects as general group atmosphere and type of coordination used. It was also noted whether the group completed their work early, or had to rush to finish the assignment.

Debriefing: Face-to-face groups were debriefed in a face-to-face session. Computer conferencing groups were either debriefed in a special on-line conference or in a face-to-face session. All participants in the face-to-face conditions were questioned regarding their adherence to the rules for communication outside the two sessions.

Measures of the Dependent Variables: A panel of three expert judges measured the dependent variables of quality of solution and creativity of solution. These judges had academic and/or professional experience in systems design. Two of the three judges met in two face-to-face sessions for training and practice on report evaluation. (The remaining judge was unable to attend either meeting.) All groups' formal reports were printed using the same word processing package and aspects of

each group's mode of communication were masked. Using a slightly modified rating form from the previous experiment, the judges rated each group on various aspects of the design (e.g., functionality and interface), written presentation, and overall quality of the analysis (22). The level of creativity contained in each group's design was also measured by the panel of judges. According to Amabile , a "product or response is creative to the extent that appropriate observers independently agree it is creative" (1, p. 359). Additionally, there is no agreement as to the appropriate subcategories to use in order to rate creativity. Therefore, we did not provide the expert judges with explicit details. Rather, we instructed them to rate the creativity of each group using the general category of "Creativity of Solution."

5. Results

5.1 Experimental validity

It was crucial to this experiment to use only graduate students in courses which were highly likely to provide subjects with the requisite knowledge and experience to engage in a fairly complex system design task. There are a very limited number of such course sections and subjects available each semester, so it was not possible to complete this as a single experiment in a single year. Though the same experimenters were involved in all conditions, following the same "script," there is always the danger that the nature or experiences of groups in conditions conducted at different periods of time may create undesirable variance. For example, though students were selected from among the same courses, the proportion from each course was not the same each semester. Additionally, conditions were run in different time periods. This means that subjects may not be homogeneous across conditions. The similarity or differences among conditions thus must be explicitly examined.

To address these concerns, we ran several statistical analyses. Concerning time, we tested for significant differences in judging by comparing the scoring results according to time period. Significant differences between time periods would indicate that time played an important role in influencing outcomes. However, our analyses show no important differences across time periods.

Another concern was that of the comparability of subjects within each of the conditions. To analyze subjects, we used background data (i.e., age, years of employment, sex, academic major) that was collected from a pre-experiment survey. T-tests indicated that subjects across conditions were different on several criteria; however, correlation analyses comparing these background variables to judges scoring of quality and creativity showed no significant correlations. Again, this indicates that these differences were not important in influencing outcomes. Although these analyses add to the validity of our findings, the results of this study should be considered exploratory rather than definitive, because of the fact that groups were assigned to different conditions at different points in time.

5.2 Experimental results

A variety of ANOVA (e.g. the GLM procedure in SAS for Windows, release 6.08), was run to test the effects of mode of communication on the dependent variables. All statistical means are calculated using the least-square means calculation. In presenting results, significance levels of .05 or better will be considered "statistically significant." Levels between .10 and .05 indicate findings that suggest a relationship may exist and will be considered "marginally significant." Since this is an exploratory study, such findings are worthy of note for further study.

Table 2 presents the means for the dependent variables. The significance levels of T-tests comparing the different communication modes are contained in Table 3. ANOVA results are contained in Table 4 for all dependent variables. The expert judges had a high level of agreement when rating the quality of solution (Chronbach's alpha=.82) and the creativity of solution (Chronbach's alpha=.81).

Creativity Measure: The expert judges rated the creativity of each group's solution on a scale from one (poor) to seven (excellent). As predicted, the creativity of solutions for the combined groups was significantly higher than the asynchronous-CC groups. Therefore, hypotheses 1.1 was supported. The combined groups were also rated significantly higher than the synchronous-CC groups, providing support for hypothesis 1.2. Likewise, the combined groups were rated significantly higher than the FtF groups. Therefore, hypothesis 1.3 was supported.

Although the solutions of the asynchronous-CC groups were rated higher in terms of creativity than those of the synchronous-CC groups as expected , the difference was not significant. Therefore, hypothesis 1.4 was not supported. Similarly, although the solutions of the asynchronous-CC groups were also rated higher regarding creativity than the FtF groups as expected, the difference was not significant. Therefore, there was no support for hypothesis 1.5.

Table 2. Least Square Group Means for Dependent Variables

	Com-bined	Asynch-CC	Synch-CC	FtF	Cond. Mean
Creativity	5.37	4.43	4.14	4.10	4.49
Quality	5.10	4.10	3.83	3.83	4.20
Sol.Satisf.	4.48	3.77	4.22	3.75	4.06
Proc.Satisf.	3.86	3.77	3.50	4.22	3.82

Table 3. Significance Levels of T-tests for Hypotheses

	Creativity		Quality	
	Com-bined	Asynch-CC	Com-bined	Asynch-CC
Asynch-CC	0.03	.	0.03	.
Synch-CC	0.00	0.47	0.01	0.54
FtF	0.01	0.43	0.01	0.56

	Sol. Satisf.	Process Satisf.
	Com-bined	Com-bined
Asynch-CC	0.00	0.82
Synch-CC	0.20	0.38
FtF	0.40	0.40

Table 4. ANOVA Results for Dep. Vars.

	Source	DF	SS	F	Pr>F
Creativity	model	3	10.72	4.05	0.01
	error	38	33.27		
Quality	model	3	11.16	3.56	0.02
	error	38	39.74		
Solution	model	3	3.90	6.12	0.0017
Satisf.	error	38	7.84		
Process	model	3	2.87	1.07	0.37
Satisf.	error	38	35.55		

Quality Measure: This expert rated category was judged on a scale from one (poor) to seven (excellent). Combined groups were rated higher than asynchronous-CC groups, as predicted, and the difference was significant. Therefore, hypothesis 2.1 was supported. The combined groups were rated significantly higher than the synchronous-CC groups, thus supporting hypothesis 2.2. Finally, combined groups were also rated significantly higher than FtF groups, providing support for hypothesis 2.3.

Similar to the results for creativity, although the asynchronous-CC groups were rated higher than both the synchronous-CC and FtF groups, neither difference was significant. Thus, hypotheses 2.4 and 2.5 were not supported.

Solution Satisfaction Measure: Solution satisfaction data were obtained via subject self-reports and varied on a scale of one (low) to five (high). As anticipated, the combined groups significantly outscored groups in the asynchronous-CC and FtF conditions. Therefore, hypotheses 3.1 and 3.3 were supported. However, combined groups did not rate themselves significantly higher than the synchronous-CC groups. Thus, hypothesis 3.2 was not supported.

Process Satisfaction Measure: Process satisfaction data were also obtained via subject self-reports and was measured using a scale of one (low) to five (high). Although we expected that the combined groups would be the most satisfied in terms of the process used to reach a solution, none of our hypotheses were supported. Combined groups were only slightly more satisfied than asynchronous-CC groups, therefore hypothesis 4.1 was unsupported. Similarly, hypothesis 4.2 was not supported as combined groups were only slightly more satisfied than synchronous-CC groups. Finally, there was no support for hypothesis 4.3 as combined groups were less satisfied than FtF groups.

6. Discussion and Conclusions

This study sought to explore the effects of different modes of communication for groups working on the upstream portions of software development. In particular, this research focused on the usefulness of combining face-to-face and computer-mediated modes of communication. Table 5 contains a summary of empirical findings.

As expected, combined groups were rated highest in terms of creativity and quality and they judged themselves as more satisfied with their solution than did the asynchronous and FtF groups. Interestingly, although synchronous-CC groups were rated lowest on quality and creativity, they rated themselves as second highest in terms of solution satisfaction. FtF groups,

Table 5. Summary of Empirical Results

Dependent Variable	Hypothesis	Prediction	Result
Creativity	1.1	Combined > Asynch-CC	supported
	1.2	Combined > Synch-CC	supported
	1.3	Combined > FtF	supported
	1.4	Asynch-CC > Synch-CC	unsupported
	1.5	Asynch-CC > FtF	unsupported
Quality	2.1	Combined > Asynch-CC	supported
	2.2	Combined > Synch-CC	supported
	2.3	Combined > FtF	supported
	2.4	Asynch-CC > Synch-CC	unsupported
	2.5	Asynch-CC > FtF	unsupported
Solution Satisfaction	3.1	Combined > Asynch-CC	supported
	3.2	Combined > Synch-CC	unsupported
	3.3	Combined > FtF	supported
Process Satisfaction	4.1	Combined > Asynch-CC	unsupported
	4.2	Combined > Synch-CC	unsupported
	4.3	Combined > FtF	unsupported

who often are most satisfied, rated themselves as least satisfied with their solutions; these groups were judged second lowest on quality and creativity measures. Although FtF groups were least satisfied with their solution, they were most satisfied with the (FtF) process used to reach a solution. Conversely, although synchronous-CC groups were second highest in terms of solution satisfaction, they were lowest regarding satisfaction with the process. Indeed, working in a room together with the ability to communicate only via electronic means appeared to be a frustrating experience for subjects in this condition.

This analysis provides empirical evidence supporting the usefulness of face-to-face communication in the initial phase of group work, followed by asynchronous communication during the execution phase of group work, followed by face-to-face communication during the final stages of group work. Combined groups significantly outscored all other communication modes on measures of both creativity and quality. Overall, groups in the combined condition produced superior requirements definitions compared to groups that met only asynchronously and groups that met only synchronously, both face-to-face and via computer-mediated communication. These results strongly suggest that combining face-to-face and asynchronous communication in different phases of group work is more effective than when restricting groups to using only synchronous meetings or asynchronous computer conferencing.

Why weren't the creativity results of the initial experiment replicated?

Results of our previously published study, where it was found that the asynchronous computer conferencing groups produced significantly more creative solutions than FtF groups, were not replicated in this analysis. Several differences exist between the first and current analyses. A different set of expert judges was used to rate groups. The judges' rating form was modified for the current experiment. Quality was measured using fewer categories and the organization of rating categories was changed. (For the first study, creativity was the last category; for the current study, it was the first category). Finally, the data set of reports for each analysis is obviously different. The FtF groups and the asynchronous-CC groups in the current analysis are a subset of groups from the initial study, representing about half of the total number of groups from the prior research. However, we speculate that the most important differences can be attributed to the inclusion of the combined condition in the current experiment. These groups were rated so much higher for both creativity and quality, that we expect that this caused groups in the other conditions to be seen as similar in the eyes of the judges. In essence, we believe that the

combined groups served to decrease the perceived variance among the other three conditions.

Can creativity be attributed to computer-mediated communication in general, or to computer-mediated communication *over time*?

Although it was expected that the level of creativity of asynchronous-CC groups would be greater than that of the synchronous-CC groups, no significant differences were found. These results could be interpreted to indicate that time does not play a significant role in the creativity of groups, and rather that, in general, it is the computer-mediated aspect of communication that accounts for differences in creativity. However, given that results from our initial study concerning creativity were not replicated in the current analysis, any conclusions regarding the importance of time versus computer-mediated communication seem unwarranted. As it stands, we still have no definitive answers in this area.

Limitations

This study has several limitations. The current analysis compared the effectiveness of four modes of communication. However, many more modes and combinations exist. In order to more fully explore the impact of computer-mediated communication on group creativity and quality, an experiment should be conducted which compares the performance of groups working in the following conditions: (1) synchronous-CC, (2) FtF, (3) asynchronous-CC, (4) FtF plus phone/fax, (5) FtF plus asynchronous computer conferencing, controlled by group phase, and (6) FtF plus asynchronous computer conferencing, with uncontrolled usage (e.g. Finholt et al.(1990)).

The current experiment was conducted over a two-year time period where subjects and groups were not randomly assigned to conditions. Although these issues appear to be insignificant, it is impossible to say, without a doubt, that they had no effect on the experimental results.

Future Research

There is ample opportunity for future research concerning the relationship between communication mode and group effectiveness. Particular attention should be given to matching communication modes with the phases of group work. Also, continued research is needed concerning the relationship among creativity, outcomes and communication mode. For instance, we still have no definitive answers on the relationships among creativity, computer-mediated communication and time. Nor do we have consistent results regarding the impact of asynchronous communication on creativity.

To continue our research in this area, we are presently conducting a new experiment comparing various communication modes, using a new Web-based interface to our computer conferencing system. In this new experiment, groups will be randomly assigned to all conditions during the same time period, thus addressing any remaining questions about the validity of results presented here.

Given the increasing prevalence of virtual teams in the workplace, research comparing the effectiveness of different modes of communication will be increasingly important. The use of Web-based systems with multi-media and hypertext links raise many issues concerning the way groups discuss and resolve problems. To what extent will the ability to mix text, audio, and visually based materials change asynchronous computer-mediated communication? How will groups using single communication modes in a closed information environment compare to groups working in the open information environment on the Web? These are only a few of the questions which remain to be addressed.

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