The Effects of Distributed Group Support and Process Structuring on Software Requirements Development Teams: Results on Creativity and Quality

ROSALIE OCKER, STARR ROXANNE HILTZ, MURRAY TUROFF, AND JERRY FJERMESTAD

ROSALIE OCKER is an Assistant Professor of Information Systems at Penn State University, Harrisburg. She received her Ph.D. from Rutgers University in computer and information science. Dr. Ocker was previously employed by Arthur Andersen & Co. She has published articles in the *Proceedings of the Annual Hawaii International Conference on Systems Science* and the *Proceedings of the Conference on Decision Sciences*. Her research interests include computer-mediated communication and distributed group support systems, group creativity and innovation, and the communication process within software development.

STARR ROXANNE HILTZ is Distinguished Professor of Computer and Information Science at the New Jersey Institute of Technology, Newark. She is also a member of the faculty of the Graduate School of Business, Rutgers University. She received her Ph.D. in sociology from Columbia University. Her recent research interests have centered on the applications and impacts of computer-mediated communication systems, including applications in education and group decision support. Her articles have appeared in *Communications of the ACM, Management Science, Human Communications Research*, the *American Journal of Sociology*, and many other journals. Recent books include a revised edition of *The Network Nation* with M. Turoff and *The Virtual Classroom: Learning without Limits via Computer Networks*.

MURRAY TUROFF is Distinguished Professor of the Computer and Information Science Department and the School of Industrial Management at the New Jersey Institute of Technology. He received his Ph.D. in physics from Brandeis University. Previously, he was employed by the Office of Emergency Preparedness, Executive Offices of the President, and by IBM. His interests are in research and development associated with the utilization of the computer to facilitate human group communication and decision making. Among his publications are articles in *Communications of the ACM*, the *Journal of Organizational Computing, Telecommunications Policy*, and *IEEE Spectrum*. Recent books include *Learning Networks: A Field Guide to Teaching and Learning Online* (coauthored with Linda Harasim, Starr Roxanne Hiltz, and Lucio Teles).

Acknowledgment: This research was partially supported by a grant from the National Science Foundation (NSF 990082). The opinions expressed by the authors do not necessarily represent those of the NSF.

Journal of Management Information Systems / Winter 1995–96, Vol. 12, No. 3, pp. 127–153

JERRY FJERMESTAD is an Assistant Professor of Information Systems in the School of Industrial Management at the New Jersey Institute of Technology. He received his Ph.D. from Rutgers University in management information systems. Dr. Fjermestad has published several articles in the *Proceedings of the Annual Hawaii International Conference on Systems Science, Technology Analysis and Strategic Management and Group Decision and Negotiation*. His current teaching and research interests are in the area of computer-mediated communication, management information systems, executive information systems, and object-oriented business reengineering.

ABSTRACT: Previous research has indicated that the creative task of deciding upon the initial specifications for a software system can benefit from a structured process to guide group interaction in face-to-face meetings, and can benefit from computer support. This 2×2 experiment is the first to look at the joint effects of a distributed asynchronous computer conferencing mode of communication (CC, as compared with face-to-face), and a structured process, on software design outcomes. Subjects were teams of graduate students in computer science and business, who designed an automated post office as a course assignment. The quality of solution produced by the CC groups was judged to be marginally higher, while CC groups were rated as considerably more creative. There were no main effects for the structured/unstructured factor, or any significant interactions.

KEY WORDS AND PHRASES: distributed group support, group creativity, group support systems, software requirements analysis.

THE UPSTREAM PORTIONS OF THE SOFTWARE DEVELOPMENT PROCESS—requirements specification and design—are considered by many to be the most important in the development of useful, usable, maintainable software [10, 17]. It is during these phases that collaborative software professionals and users work to achieve some consensus on the general characteristics of the new system in question [49]. More than half the cost of the development of complex computer-based information systems is attributable to decisions made in these upstream portions of the software development process [44]. Arguably, then, the key to developing effective information systems lies in a team's ability to *define requirements*, since this is the first step in the software development process. Performing these upstream functions ineffectively will significantly and negatively impact the outcome of the system under development [4, 6, 62] as decisions made during these initial stages drive decisions made throughout the remainder of the development process. Incorrect system requirements are largely the cause of cost and schedule overruns that are still fairly prevalent in information systems development [62].

Thus, the importance of the upstream portions of the development process has become appreciated, as well as the fact that research in this area can improve the quality and productivity of information systems [10, 56]. To provide effective support, it has been increasingly suggested that the development of information systems in general, and the upstream portions of the development process in particular, could benefit from the infusion of *creative* and *innovative* solutions [9, 21, 59]. One approach is to provide support for the upstream portions of software development through the use of group support systems [19, 34, 14]. This paper reports on an experiment that investigated the usefulness of computer conferencing to support groups working (1) on requirements definition, (2) in a distributed asynchronous environment. Asynchronous refers to the dimension of time—at *different times*—while distributed refers to the dimension of space—at *different places*. Thus, members of distributed asynchronous groups "meet" or communicate with one another at different times, from different places.

The distributed asynchronous form of group interaction has obvious benefits. Group members do not have to be physically in the same place to meet, nor must they communicate with one another at the same time. These two characteristics of distributed asynchronous communication greatly extend the definition of what constitutes a meeting. These loosened constraints can add value to the organization by increasing the means with which groups can accomplish work. However, there are also disadvantages. Points of reference for indexing communication by time, place, and talk sequence are all missing [29]. As communication occurs over time, days can elapse between communication events, resulting in communication that can seem disjointed.

Another coordination problem is finding workable substitutes for temporal sequence as an ordering mechanism. In an asynchronous discussion, the norm is for many topics and subtopics to be active at once, and sometimes more than one person makes entries simultaneously, perhaps on different topics. How does the group order and coordinate what can seem chaotic? One approach for dealing with these problems of coordination is (1) to provide structuring mechanisms for groups to use to organize their communication and (2) to sequence the problem solving process followed by groups to accomplish work.

Where creative solutions to difficult problems are the desired outcome, some degree of structure can be a stimulus to the triggering of ideas (e.g., brainstorming). However, too much structure, or the wrong structure, can limit the creative process. In the distributed asynchronous environment, structure becomes an important component in the organization and comprehension of the group view [31, 60]. While synchronous groups can often vary the degree and type of structure dynamically as needed, this is more difficult for distributed asynchronous groups that are dependent on both structure and process rules for coordination. Hence, understanding in detail the trade-off between structure and creativity becomes critical for the design of an asynchronous process.

In this paper, we report on results of our first experiment conducted to investigate the usefulness of the distributed asynchronous mode of interaction and communication for groups working on requirements definition and high-level design. We also investigate the usefulness of a structured problem-solving approach for accomplishing this activity. The dependent variables we report on are (1) creativity of design solution and (2) quality of design solution. Distributed asynchronous groups use a computer conference (CC) to conduct all of their work. These groups are referred to as CC groups throughout the remainder of this paper.

Background

Minority Influence, Group Creativity, and Quality

UPSTREAM DEVELOPMENT IS AN INHERENTLY CREATIVE PROCESS [27]. The end-product is the creation of an artifact—something that previously did not exist. Creativity at the group level is not merely the summation of each group member's individual creativity. Prior research has found group creativity to be impacted by a variety of antecedents, including group structure (e.g., leadership), group composition (e.g., diversity, size), and group characteristics (e.g., cohesiveness, longevity) [69]. This previous research has been criticized for being largely atheoretical and ignoring relevant research from the area of social psychology [36]. However, several researchers (e.g., [67, 69]) suggest that research on minority influence provides a very plausible account of intragroup processes leading to creativity.

Minority influence is a theory pertaining specifically to the study of social influence and describes the situation wherein a minority opinion holder influences the majority opinion holders within a group. Nemeth et al. [45, 46, 47, 48] are credited with relating the theory of minority influence to group creativity. In a series of four experiments [46, 47, 48], Nemeth and colleagues found the presence of minority influence to stimulate independent and divergent thought, so that groups considered issues and problems from more perspectives. This resulted in group members detecting and exploring *new, novel, and more correct solutions*.

Nemeth et al. [45] argue that the key to the minority's influence is its display of *independent and consistent behavior over time*, coupled with a willingness to confront the status quo actively. An active minority causes the group to consider numerous alternatives, one of which is the position proposed by the minority. The group's thought processes are marked by *divergent thought* as a result of consideration of an expanded set of alternatives. Because the minority is *unwilling to conform* to the majority opinion, *conflict* is evident within the group as the group reexamines its problem-solving efforts. This reexamination requires *more cognitive effort* on the part of group members as problems are considered from more perspectives. This process of reexamination increases the likelihood that the group will detect more creative and correct solutions.

GSS Dependent Variables Related to Minority Influence

Given our interest in creativity and quality, and in light of the previous discussion on minority influence, the pertinent question is: Is it likely that CC groups will experience minority influence or those antecedents present in minority influence? After a thorough review of the literature comparing computer-supported groups to unsupported face-to-face (FtF) groups, it appears that characteristics of minority influence relate to a variety of GSS dependent variables. These relationships are depicted in Table 1, as well as the desired effect of each GSS variable in order to enhance minority influence. A discussion of each of these group characteristics follows.

Table 1. Relationship between Minority Influence, Creativity, and GSS Dependent Variables

Group characteristics	Minority influence	GSS dependent variable	Desired effect
Behavior	Independent behavior	Uninhibited behavior	Increase
	Consistent behavior over time	Time to complete task	Increase
Expressed viewpoints	Divergent	Equality of participation	Increase
		Number of ideas/opinion giving	Increase
Agreement/conformity	Low conformity	Consensus/ cohesion/conformity	Decrease
Conflict	High conflict	Conflict	Increase
Effort	More cognitive effort	Coordination	Decrease
		Time to complete task	Increase

The relationship of GSS dependent variables to group characteristics prevalent in minority influence is shown, along with the desired effects of GSS variables to enhance minority influence.

Behavior

There are two important aspects of behavior that the minority must possess in order to exert influence: (1) independent thought, (2) which is perceived as consistent over time. Uninhibited behavior has been associated with computer-mediated communication under some circumstances [14, 26, 41, 54, 66]. Uninhibited behavior is typically defined as the frequency of remarks containing swearing, insults, name calling, and hostile comments [35]. These characteristics of uninhibited behavior indicate a degree of independent behavior as well as a lack of conformity. As for the dimension of time, GSS groups (especially those whose sole means of communication is via the computer) tend to require more time to conduct work when compared to FtF groups (e.g., [14, 54, 66]). Thus, there should be an increased chance that a minority opinion holder would be able to display independent and consistent behavior over a period of time, when communicating electronically.

Expressed Viewpoints

Minority influence is characterized by the expression of divergent viewpoints—that is, viewpoints that are not only different from the majority, but are freely expressed. In the computer-mediated communication and GSS areas, it has been found that the technology tends to promote equality of participation [1, 12, 14, 18, 25, 26, 30, 54, 66, 71], which in turn leads to more opinion giving and the expression of more ideas [30, 54]. For example, electronic brainstorming studies have found that these groups produce more unique ideas than unsupported FtF groups and noninteracting groups [22, 23, 24]. It is believed that electronic communication decreases the amount of lost ideas by eliminating the need for turn-taking typical of FtF conversations and by providing a group memory.

Agreement/Conformity

For minority influence to prevail, agreement and conformity within the group should be at low levels. Independent thought and action are aided by groups that are not too cohesive, as cohesive groups tend toward groupthink [33]. Several GSS studies have measured the degree of opinion change and choice shift, cohesion, and conformity within electronically supported groups as compared with traditional FtF groups [1, 5, 7, 20]. There is less agreement within the research findings in these areas, making any generalizations difficult. Also, a group of studies have looked at the degree of consensus and agreement [1, 24, 26, 30, 32, 65]. Generally, empirical results indicate that GSS groups experience greater difficulty in reaching consensus, as compared with FtF groups.

Conflict

The minority opinion holder's consistent behavioral style that contradicts the majority creates both cognitive and social conflict. Cognitive conflict results, due to the necessity to ascertain the correctness of opposing viewpoints. Social conflict ensues as the minority is unwilling to compromise with the majority. Conflict has been examined in a handful of GSS studies [24, 41, 43, 52, 66]. Results vary between studies, although it appears that the use of a GSS tends to decrease the level of conflict reported within the group.

Effort

It is believed that when there is an active minority, more cognitive effort is required of group members. Individuals must attend to more aspects of the problem situation, as various alternatives must be considered and conflict resolved. Within the GSS domain, it is well accepted that computer-mediated communication requires significantly more effort than traditional FtF communication [20, 55, 71]. Coordination of group activity is more difficult, especially in an asynchronous environment, and thus requires an increased expense of effort. In addition, GSS groups must work longer than FtF groups in order to reach consensus.

In general, then, it appears that GSS usage can result in many of the same characteristics that are required for the existence of minority influence and that have been found to enhance levels of creativity in groups. In fact, Rao and Jarvenpaa [53] associated minority influence theory with two features in a GSS: parallel input of ideas and anonymity. They reason that both of these features increase the amount of participation and thus increase the likelihood of exposing minority opinions. In support of this linkage, McLeod and Elston [42] found that minorities were most influential in computer-mediated circumstances, as opposed to FtF conditions. Thus, there is both theoretical and empirical support in the GSS literature concerning the prospect of minority influence in a GSS environment.

Coordination, Distributed Asynchronous Communication, and Problem-Solving Approach

Coordination is the set of tasks and processes by which groups of actors carrying out activities manage interdependencies, in order for them to perform effectively as a group [39]. Empirical findings indicate that actual design activities account for less than half of the meeting time of unsupported FtF design teams working on the early stages of design, while coordination activities required at least 20 percent of the meeting time [50]. Also, research has shown that software teams working on upstream development activities are plagued by lost and forgotten information, seemingly due to lack of a systematic approach for handling vast amounts of information [50, 64]. Although the need for coordination is inherent in all group problem-solving activities, as previously described, distributed asynchronous groups have additional and unique coordination problems beyond those experienced by FtF groups.

Based on these needs of groups working during the upstream portions of development and the special coordination needs of distributed asynchronous communication associated with temporal sequencing and ordering of communication, a structured problem-solving approach was developed. This problem-solving approach was based on concepts and techniques from the area of design rationale. Design rationale is a structure imposed to represent certain aspects of the decision-making process that occurs during the design of an artifact. Without an imposed structure, design rationale is nothing more than free text, such as notes taken during design meetings. Various methods have been devised to provide structure for a design rationale.

Design rationale methods have been successfully used for accomplishing design in field studies (e.g., [70]), where benefits have accrued in the areas of improved communication and team memory. In addition, Olson et al. used design rationale structures for encoding actual design activity [50], showing that there is a good fit between upstream development activities and design rationale concepts. Given our desire to assist design groups in general, and distributed asynchronous groups in particular, in the area of coordination of communication, we combined two specific design rationale approaches: (1) Issue Based Information System (IBIS), originally developed by Kunz and Rittel [37] for use in argumentation, and (2) Design Space Analysis, developed by MacLean et al. [38]. IBIS was developed for the purpose of supporting argumentation by explicitly structuring communication for both pro and con ideas regarding the generation of various alternative solutions. IBIS has been implemented to document design meetings, as a *historical record* of the problem-solving and decision-making process [70]. Design Space Analysis (DSA) is used *during the process* of design, to actively build the structures of argumentation as design discussions take place. We combined aspects of IBIS and DSA to sequence the process of design activity and to structure the argumentation surrounding the various issues of the design process.

Research Framework, Experimental Design, and Hypotheses

HACKMAN AND MORRIS [28] PROPOSE THAT A MAJOR PORTION of variation in measured group performance is controlled by three general summary variables: (1) the knowledge and skills of group members, (2) performance strategies used by the group in carrying out the task, and (3) the amount of coordination and effort exerted by group members on the task. They argue that it is possible to substantially affect the level of group effectiveness by controlling or influencing these three summary variables, and that the relative importance of each summary variable is contingent upon the task at hand. For a task requiring creativity, the development of new strategies and increased member skill are of paramount importance. However, for CC communication, coordination of member effort is also very important.

Each summary variable is impacted by the type of interaction such that either process gains or process losses [58] occur (see Table 2). These gains and losses in turn impact the performance effectiveness (outcome) of the group. Group effectiveness can be improved above the level expected resulting from process losses by altering the input factors.

The objective of this empirical study is to investigate the usefulness of a computer-conferencing type of GSS to support groups working on the upstream portions of systems development. The theoretical framework for this study is presented in Figure 1 and is adapted from Hackman and Morris [28] and Woodman et al. [69]. Group-level antecedents impacting minority influence and creativity include group member behavior, participation, diversity, cohesiveness, conformity, conflict, and member effort. The two independent variables of interest in this study are mode of communication and problem-solving approach. Mode of communication consists of distributed asynchronous computer conferencing and traditional FtF communication. Problem-solving approach compares groups who followed a highly structured and imposed process with unstructured groups having no imposed process. The independent variables are expected to moderate social influences within the group, which in turn impact antecedents. The process of interaction among the group-level antecedents, the independent variables, and social influences will impact the level of creativity exhibited within each group. The interaction process will result in gains and losses impacting member knowledge and skill, group performance strategies, and coordination of member effort. These summary variables directly impact the group outcome, affecting the creativity and quality of group performance, and also the satisfaction of members.

Table 2. Summary of Proposed Functions of Group Interaction

1. Member knowledge and skills
Process losses—interaction is less-than-perfect means for applying member talents to the task
Potential gains—interaction is means for generation of new knowledge or skill by members
2. Performance strategies for carrying out the task
Process losses—interaction serves to implement less-than-perfect preexisting strategies
Potential gains—interaction serves to reformulate strategic plans to increase their task-appropriateness
3. Level and coordination of member effort
Process losses—interaction is less-than-perfect means to coordinate member effort
Potential gains—interaction enhances coordination and member effort

Hackman and Morris propose that variation in group performance is controlled by three summary variables. Each summary variable is impacted by the type of interaction such that process gains or process losses occur.

Hypotheses on Creativity and Quality

Based on the previous discussion of creativity and minority influence, and drawing on empirical research comparing computer-mediated communication versus unsupported FtF groups, we make the following speculations which are depicted in Figure 2. CC groups will feel less threatened than FtF groups due to reduced social cues [57]. Coupled with more equal participation, CC groups will experience increased information sharing. This will positively impact the level and amount of member knowledge (summary variable), resulting in problem solutions of higher quality.

The uninhibited behavior in individuals communicating electronically points to the likelihood that members of CC groups will feel less pressure to conform. In addition, distributed groups are by their nature loosely joined, and therefore not likely to be as cohesive as their FtF counterparts. These characteristics coupled with more equal participation should lead to the sharing of more diverse opinions within the group. Diverse opinions lead to divergent thought and conflict. Although these conditions will increase the probability for a creative solution, it is necessary that the minority opinion holder(s) exhibit consistent behavior patterns over time in order to have influence over the majority opinion holders. CC groups have an increased opportunity for communication, and more time/less pressure when developing and presenting their opinions. They tend to work harder and communicate longer. Therefore, we speculate that minority opinion holders in the CC groups will be perceived as more consistent than their FtF counterparts, and thus will be more likely to exert influence. Minority influence should increase the chances for the development of new performance strategies (summary variable) and therefore novel solutions to the problem, resulting in increased levels of creativity. Therefore we hypothesize the following main effects:

H1. CC groups will produce solutions of higher quality than FtF groups.

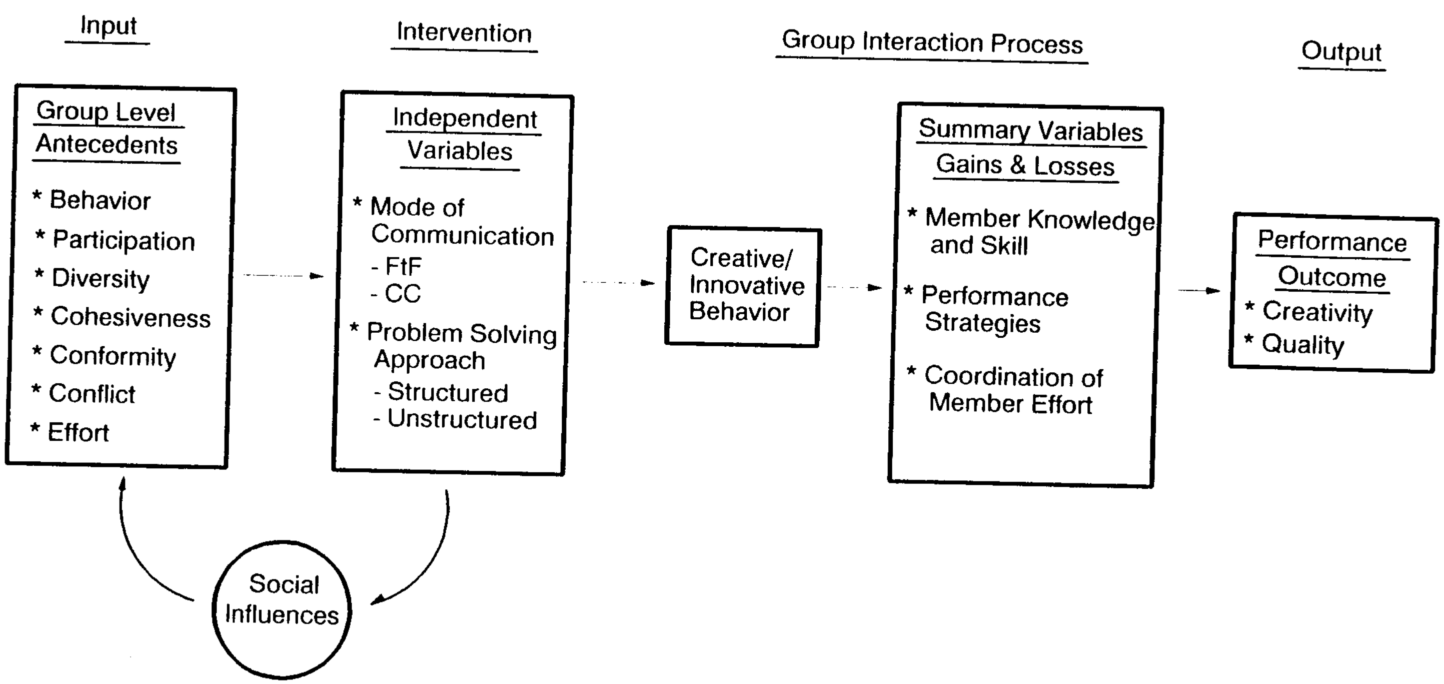

Figure 1. Theoretical Framework (adapted from [28, 69]. The process of interaction between the group-level antecedents impacting minority influence, the dependent variables, and social influences will influence the summary variables, resulting in differences in creativity and quality of the group outcome).

H2. CC groups will produce more creative solutions than FtF groups.

There is no prior empirical basis upon which to hypothesize the effect on quality and creativity of a structured approach based on design rationale concepts for groups working on requirements definition and high-level design. In the GSS research domain, the only structured approach that has been looked at from a creative perspective is electronic brainstorming where the number of unique ideas is measured. The structured approach in this experiment was selected for its fit with the task for the primary purpose of providing coordination, especially to the distributed asynchronous groups. After an extensive review of the literature, an analysis was made of the effect of structure on group characteristics associated with minority influence and creativity. Based on an educated guess about these effects, where possible, we speculate upon the resulting impact on creativity and quality. These speculations are presented in Table 3.

With respect to the group characteristic of behavior, there is no basis from the literature upon which to make any speculation. However, concerning the dimension of time, it is expected that structured groups will experience more time pressure since there is a strict schedule and sequence of events that must be followed. Time pressure is expected to decrease the amount of creativity and quality within the group. In regard of the group characteristic of expressed viewpoints, the structured approach is designed to increase group member participation. Thus, structured groups are expected to exhibit more equal participation and hopefully share more divergent views than unstructured groups, resulting in increased levels of creativity and quality. Due to increased participation and expressed viewpoints, structured groups are expected to have lower levels of conformity and agreement than unstructured groups. This should result in higher levels of conflict for structured groups, which would require increased effort. These attributes should work together to increase the amount of creativity and quality within these groups. Therefore, overall, it is speculated that structured groups may exhibit higher levels of creativity and quality than unstructured groups. However, since what process unstructured groups will follow is unknown, the following hypotheses are very tentative:

H3. Structured problem-solving groups will produce solutions of higher quality than unstructured problem-solving groups.

H4. Structured problem-solving groups will produce more creative solutions than unstructured problem-solving groups.

Face-to-face communication and interaction are much richer than asynchronous communication [11]. Although the problem-solving structure was chosen because of its capability to structure communication, which includes a diversity of opinions, and also for its fit with the activity of design, it has been argued that FtF design groups do not need this added coordination [50]. It is suggested that the activity of high-level design has its own inherent structure naturally embedded within the task, and that adhering to an IBIS derivative of argumentation would impede the productivity of FtF groups working on design. However, we argue that the opposite is true for CC groups;

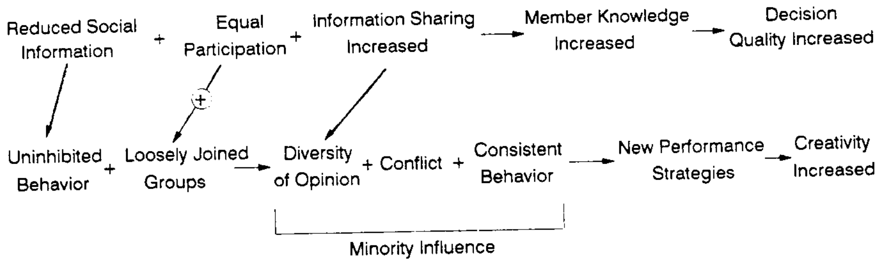

Figure 2. Impact of GSS Dependent Variables on Quality and Creativity

coordination is difficult [20, 55] and some structure [3, 15] is required to ease the cognitive burden of distributed asynchronous groups. Because of the need for differing amounts of coordination (summary variable) between the FtF and CC groups, we predict that there will be an interaction effect such that:

H5. CC structured groups and FtF unstructured groups will produce solutions of higher quality than CC unstructured groups and FtF structured groups.

H6. CC structured groups and FtF unstructured groups will produce more creative solutions than CC unstructured groups and FtF structured groups.

Method

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. [51], 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 [40].

Subjects consisted of graduate students in CIS and MIS courses at the New Jersey Institute of Technology (NJIT) and M.B.A. courses 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.

A total of 41 groups and 218 participants started the experiment; all groups completed the experiment; only one individual dropped out (due to illness). Prior to the start of the experiment, it was decided that group size would be allowed to range from four to seven members. The last group that was run consisted of only three

Table 3. Effect of Structured Approach on Creativity and Quality

Group characteristic	Effect of structure	Effect on creativity and quality
Behavior		
Independent	Unknown	Unknown
Consistent over time	Unknown	Unknown
Time	More pressure	Decrease
Expressed viewpoints	More participation	Increase
	More divergent viewpoint	Increase
Agreement/conformity	Less	Increase
Conflict	More	Increase
Effort	More	Increase

Results of an analysis of the impact of structure on group characteristics associated with minority influence.

members and was therefore not included in the experiment. Thus, 40 groups and 214 subjects are included in the analysis. Although every attempt was made to assign groups to conditions so that each condition was balanced according to number of groups, group size, and academic major, this goal was not achieved. As Table 4 demonstrates, the CC/structured condition had the least number of groups (nine), while the FtF/structured condition had the most groups (eleven). Groups of five and six dominated, numbering seventeen and sixteen, respectively. With the exception of the CC/structured condition, there was a fairly even percentage of CIS/MIS majors among the other three conditions. However, the CC/structured condition had a much higher percentage of CIS/MIS majors (90 percent) with a proportionately smaller percentage of management/M.B.A. majors (6 percent).

Structured Approach

The structured approach was pilot tested extensively, using four groups to test the FtF/structured condition and an initial set of seven groups to test the CC/structured condition. After each pilot study, discussions with the group members were conducted to obtain feedback on the structured approach and experimental procedures. Structure and procedures were modified accordingly; for the CC/structured condition, two additional pilot groups were run to test new and revised structures and procedures prior to the start of the experiment.

Experimental groups in the structured conditions followed a sequence of steps contained in three main phases:

Table 4. Distribution of Groups by Condition Along with Group Composition by Academic Major

Group size	CC/S	CC/U	F/S	F/U	Total groups
7				2	2
6	2	4	5	5	16
5	6	6	4	1	17
4	1		2	2	5
Total groups	9	10	11	10	40
% CIS/MIS	0.90	0.64	0.64	0.51	
% Mgt./M.B.A.	0.06	0.30	0.19	0.40	

1. Generation of alternatives: Each group member individually develops his or her own design alternative of an automated post office. There is no group interaction during this phase—each person works alone. The outcome of this phase is the individual design alternatives—one design alternative per group member.
2. Period of critical reflection and individual evaluation of alternatives: Each group member reviews other members' design alternatives, making pro and con comments on each alternative. Pro comments are comments in support of various aspects of a design alternative; con comments are comments critiquing aspects of a design alternative. These comments are attached to the alternative so that all members have access to them. The outcome of this phase is the individual evaluation of each design alternative.
3. Group evaluation of alternatives and consensus reaching: The goal of each group is to reach consensus on the contents of the final design and write the formal report containing details of the design. Three steps are completed in this phase: (a) Each group member individually reviews other members' design alternatives and pro and con comments, noting aspects of each alternative he or she feels should be included in the formal design. (b) The group develops a list containing possible alternatives. (c) The group uses this list to debate and discuss the design alternatives to reach consensus on the formal report. Steps (b) and (c) are iterative and can be repeated as many times as necessary, within the allotted timeframe. The outcome of this phase is the formal report describing the group's design of the automatic post office.

Technology and Facilitation

The CC groups communicated using the EIES 2 computer conferencing system developed at NJIT. Each CC 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

The experiment lasted two weeks. All groups met face to face for training and used the same practice problem, called Entertainment for Dutch Visitors [51]. CC groups were trained on the communication features of EIES 2 while the structured groups were trained on the steps in the approach. (Thus, the CC/structured groups were trained on both the use of EIES 2 and the structured approach.) Training was completed within two hours for CC groups, after which they departed to work on the APO task on-line. Training for FtF groups was completed within one hour. The FtF groups remained together to begin work on the APO task. For data-collection purposes, all participants completed a background questionnaire.

Procedures

The *CC/structured* groups followed a strict schedule. Phase 1 was to be completed within two days after training and phase two within five days after training. Phase three, steps (a) and (b) were to be completed within eleven days after training, while step (c) was to be completed within fourteen days of the training date. The *CC/unstructured* groups were not given any process or structure to follow. They were simply told that by the end of the two-week period, their group report had to be submitted on-line. All CC groups were explicitly instructed to communicate only within their respective computer conference.

Face-to-face groups met for two sessions, spaced exactly two weeks apart. In session one, members of the *FtF/structured groups* had one hour to complete their individual design alternative (phase 1 of the imposed process). At the end of the session, the design alternatives were collected by the facilitator and copies were made. One copy of each alternative was then mailed to each group member on the day following session one. During the two-week interim period, each group member completed phase two of the structured approach. Group members brought pro and con comments back with them to session two, where they were read by each group member. In session two, groups had two and a half hours to work on phase 3 of the structured approach.

The *FtF/unstructured* groups worked on the APO task for one hour in session one. Group members were permitted to work independently on the APO task during the two-week interim between sessions one and two; they were instructed not to communicate with fellow group members during this time. Session two consisted of the groups working on the APO task for two and a half hours.

The content and layout of the formal report was determined by each group. Most FtF groups were provided with a word processor to use in the second session, at their discretion, in order to write their report. Two groups were unable to use a word processor because of technical problems. Their reports were handwritten and later transcribed using a word processor. This did not seem to affect their performance negatively, as both groups produced two of the longer reports for this condition and their reports were not judged adversely by the expert judges.

All groups had a leader who volunteered for the role at the end of the training session, sometimes with encouragement from the facilitator. For the FtF groups, the leader was only responsible for ensuring that any materials generated in session one were brought to the second session. For the CC groups, the leader was only responsible for ensuring that the formal report was submitted on EIES 2 by the end of two weeks.

All groups completed a task and postexperiment questionnaire. 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. CC groups were either debriefed in a special on-line conference or in a face-to-face session. All participants in the FtF conditions were questioned regarding their adherence to the rules for communication outside the two sessions.

Measures of the Dependent Variables

The quality of each group's solution, as contained in the group's final report, can be considered from several aspects [51]: functional requirements analysis and design (system functionality, system interface, and coherence of these ideas), nonfunctional requirements analysis (people involved in running the facility, maintenance of the system, and costs and benefits), the written quality of the formal report (organization and clarity), and finally, the general, overall quality of the formal report. These various aspects of solution quality were measured by a panel of three expert judges, all of whom had academic and/or professional experience in systems design. All groups' formal reports were printed using the same word-processing package and aspects of each group's mode of communication were masked.

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" [2, p. 359]. In addition, there is little 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."

Results

SINCE GROUP SIZE WAS ALLOWED TO VARY BETWEEN FOUR AND SEVEN MEMBERS, a one-way analysis of variance was run on group size for all dependent variables. Results showed that there were significant differences due to size for two measures—creativity of solution and nonfunctional requirements. For creativity, significant differences occurred between groups of size four and five and groups of size five and six. For nonfunctional requirements, significant differences occurred between groups of size four and all other group sizes (i.e., 4 and 5, 4 and 6, and 4 and 7). In addition, there was an unbalanced distribution of information systems majors and M.B.A.s across conditions, along with a significant correlation of IS major with both measures of creativity and quality. Due to these circumstances, two separate analyses of covariance were run: one using both IS major and group size as covariates and another using only IS major as a covariate. When comparing ANCOVA results, no significant differences occurred between the results of the two-covariate analysis (group size and IS major) and the single (IS major only) analysis. Thus, differences in group size were not a driving force. Therefore, results presented in the following section are run for a two-factor analysis of covariance, using only information systems major as the covariate. The GLM procedure in the SAS system for Windows, release 6.08, was run to test the effects of mode of communication and problem-solving approach, and the interaction of these factors on the dependent variables. All statistical means are calculated using the least-square means calculation after regressing out the effect of information systems major from the data. In presenting results, significance levels of 0.05 or better will be considered "statistically significant." Levels between 0.10 and 0.05 indicate findings that suggest a relationship may exist and will be considered "marginally significant." Since this is the first study exploring requirements analysis and design from a fully distributed, asynchronous environment, such findings are worthy of note for further study.

Table 5 presents the descriptive statistics for the dependent variables. ANCOVA results are contained in Table 6 for all dependent variables. The panel of three expert judges had a somewhat disappointing level of agreement when rating the quality of solution (Cronbach's alpha = 0.65) although the coefficient for creativity of solution was quite acceptable (Cronbach's alpha = 0.82). Intercorrelations among expert-rated dependent variables were computed. The level of association between overall quality and creativity ($R = 0.68$) indicates that they are related but distinct dimensions in the judges' minds.

Quality Measures

All expert-rated categories were judged using a scale from one (poor) to ten (excellent). Concerning the quality measure of *functional requirements and design,* CC groups were rated higher (7.42) than the FtF groups (6.71); this difference was marginally significant at $p = 0.09$. As for the *nonfunctional quality* measure, CC groups (5.86) were not significantly different than FtF groups (5.33) ($p = 0.46$). Likewise, for the measure of *written quality*, again CC groups (7.46) did not score significantly different from FtF groups (7.15) ($p = 0.45$). However, for the measure of *overall quality*, CC groups (7.36) were rated higher than FtF groups (6.52); this difference was marginally significant at $p = 0.08$. The measure of functional requirements and design was highly correlated with overall quality (0.91), thus,

Table 5. Least-Square Group Means, after Regressing out the Effect of IS Major, for the Dependent Variables of Quality and Creativity

	Approach	Communication		Condition means
		CC	FtF	
Functional requirements and design	Structured	7.47	6.18	6.82
	Unstructured	7.38	7.23	7.30
	Cond. means	7.42	6.71	7.03
Nonfunctional requirements	Structured	6.22	5.00	5.61
	Unstructured	5.50	5.67	5.58
	Cond. means	5.86	5.33	5.57
Written quality	Structured	7.57	6.85	7.21
	Unstructured	7.35	7.45	7.40
	Cond. means	7.46	7.15	7.29
Overall quality	Structured	7.44	6.06	6.75
	Unstructured	7.29	6.98	7.13
	Cond. means	7.36	6.52	6.91
Creativity	Structured	6.54	5.09	5.81
	Unstructured	6.62	4.79	5.71
	Cond. means	6.58	4.94	5.72

the components for which there was any level of significance appear to pertain to the core functional analysis and design activities rather than the nonfunctional (managerial issues) requirements or the quality of the written presentation itself. In summary, there was marginal support for hypothesis 1.

As is evident from Table 6, there were no significant or marginally significant differences between structured and unstructured problem-solving groups on any measure of quality, showing no support for hypothesis 3. Similarly, hypothesis 5 was not supported, as no interaction occurred.

Creativity Measure

As predicted, the CC groups scored significantly higher on the measure of creativity than did the FtF groups (6.58 versus 4.94, $p = 0.005$), supporting hypothesis 2. However, since there was no difference associated with the structured/unstructured factor, hypothesis 4 was not supported. Likewise, no interaction occurred, so that hypothesis 6 was not supported.

Discussion and Conclusions

THE MAIN OBJECTIVE OF THIS STUDY WAS TO EXPLORE the effects of distributed

Table 6. ANCOVA Results for Quality and Creativity

	Source	DF	Sum of squares	*F* value	*Pr* > *F*
Functional requirements and design	Model	4	18.73	3.10	0.03
	Comm. mode	1	4.63	3.07	0.09
	Approach	1	2.12	1.41	0.24
	Interaction	1	3.19	2.11	0.15
	IS major	1	4.93	3.26	0.08
	Error	35	52.86		
Nonfunctional requirements	Model	4	14.76	0.81	0.53
	Comm. mode	1	2.59	0.57	0.46
	Approach	1	0.01	0.00	0.96
	Interaction	1	4.74	1.04	0.31
	IS major	1	3.81	0.84	0.31
	Error	35	159.17		
Written quality	Model	4	6.55	1.13	0.36
	Comm. mode	1	0.85	0.59	0.45
	Approach	1	0.32	0.22	0.64
	Interaction	1	0.62	1.12	0.30
	IS major	1	2.39	1.65	0.21
	Error	35	57.16		
Overall quality	Model	4	21.15	2.69	0.04
	Comm. mode	1	6.47	3.29	0.08
	Approach	1	1.34	0.68	0.41
	Interaction	1	2.77	1.41	0.24
	IS major	1	5.57	2.83	0.10
	Error	35	68.85		
Creativity	Model	4	38.81	3.59	0.01
	Comm. mode	1	24.51	9.08	0.005
	Approach	1	0.11	0.04	0.84
	Interaction	1	0.35	0.13	0.72
	IS major	1	4.40	1.63	0.21
	Error	35	94.50		

asynchronous communication and problem solving on software design teams working on a creativity task. The results were marginally significant for quality measures associated with the core activities of functional requirements analysis and design. However, considering all the individually rated component measures of quality, CC groups outscored their FtF counterparts on each measure. Given that the structured approach did not significantly impact any groups, especially CC groups, this finding concerning quality is encouraging. All CC groups, where members could only "meet" electronically to discuss their work, were not only able to complete the task, but were judged to perform as well or better on all measures of quality as compared with traditional groups. However, determining an effective process to aid distributed asynchronous groups in coordinating their work efforts still remains to be accomplished.

Why Were CC Groups More Creative?

The major finding of this study is that distributed asynchronous CC groups developed requirements definitions and high-level designs that were significantly more creative than FtF groups. "Supporting creative group problem solving requires that the group be provided an environment and tools that helps minimize the blocks to creativity of members, enhances creative traits and skills of individuals, and enables them to proceed through creative problem solving processes" [16, p. 290]. The act of communicating asynchronously in a dispersed setting over a period of time appears to enhance creativity.

On face value, it seems that the theoretical model has strong potential in predicting creativity of CC groups. However, the model input of group-level antecedents was not measured or controlled in this study. Thus, it is impossible to know whether these model antecedents are interacting with the dependent variables in such a way as to influence creativity positively, or whether the creative result produced by CC groups is predominantly due to other influences. Furthermore, if the antecedents are exerting influence, which ones account for the most influence? This study does not provide information to address these issues. Therefore, the degree of fit between the model and the results is not ascertainable from this study. For example, it is indeterminable whether the distributed asynchronous aspects of the GSS used in this study account for the most significant impact on the antecedents or whether these differences are due, more fundamentally, to the use of technology in general. We do not know whether similar results would be obtained for groups communicating synchronously via computer. Although this study leaves many unanswered questions, it does provide a strong first step in showing that usage of a GSS significantly enhances group creativity beyond the idea-generation stage through to the idea-development stage of problem solving. The specifics of the theoretical model remain to be tested.

Why Didn't the Structured Problem-Solving Approach Make Any Difference?

The results of this study indicate that the structured approach had no significant effect on the performance of either the CC groups or the FtF groups, although FtF/structured groups were consistently rated the lowest of the four experimental conditions on quality measures. There are a variety of possible explanations for why the structured approach did not result in any marked difference between conditions. System restrictiveness refers to the way in which a decision support system limits users' decision-making processes to a subset of all possible processes [61]. Using this perspective, then, one obvious explanation is that the structured approach restricted the subjects' decision-making processes to an inappropriate subset for either the type of task or the type of coordination needed by the (CC) groups. As for the question of fit between the structured approach and task type, similar design rationale structures have been successfully used with design practitioners [8, 50, 70]. Thus, it appears that there is a good fit between the type of structure used in this experiment and the upstream activities of development groups. Concerning the aspect of coordination, however, it is unknown whether the characteristics of the structured approach actually help groups in coordinating their work efforts. For example, phase one of the structured approach was based on the Nominal Group Technique, and therefore was an individual activity. This phase may have thwarted cumulative group processes posed by the theoretical framework.

Another possible explanation for the lack of impact of the structured problem-solving approach is that unstructured groups were able to devise equally effective processes to use in completing the APO task. To address this issue, a sample of four groups each in both the CC/unstructured and FtF/unstructured conditions was analyzed. For the FtF/unstructured groups, audiotape recordings of both sessions were content-analyzed for groups FN1, FN4, FN6, and FN8. These groups were chosen because of the clarity of the audiotape recordings. (Some groups conducted much of their sessions using their foreign native tongue—e.g., Chinese—thus, eliminating them from analysis by these researchers.) For the CC/unstructured groups, conference comments were analyzed for groups 42, 48, 54, and 59. These groups were randomly chosen by an individual not involved with the experiment. The content analysis revealed that all of these groups conducted some form of idea generation for some period of time, whereby various ideas were generated and discussed. The groups structured themselves to differing degrees in order to accomplish the task of writing the report, with some groups appearing to be more structured than others. Thus, although none of these groups used a structure that was very similar to that used by groups in the structured conditions, all groups imposed some structure of their own to complete the APO task. Perhaps these self-imposed structures, amounting predominantly to idea generation, provided the right type and amount of structure necessary to accomplish the task. In their extensive study of design teams in the field, Olson et al. [50] speculated that use of a design rationale by traditional FtF design groups could impose too much structure and thus be detrimental. From the results of our study, it appears that these researchers were correct. Compared with distributed asynchronous groups, FtF communication is a richer environment, requiring less coordination among group members with regard to communication.

Another possible explanation for the lack of effect of the structured approach could be due to characteristics of the task itself. The structured approach was developed with a complex task in mind. The utility of a structure is tied to the complexity of the problem—for a structure to be beneficial, the task must be complex to some degree. In support of this, Wood and Nosek [68] found that for groups with seven to ten members, use of a GSS was superior to manually supported groups only for more complex tasks. Thus, they found that technology will not have positive results, compared with manual versions of the same process, unless the task is complex. Similarly, if our subjects judged the APO task to be relatively straightforward and algorithmic rather than heuristic in nature [2], then additional structure, especially for FtF groups, would not be needed. Along these lines, subjects rated the analyzability and ambiguity of the APO task. On average, subjects rated the APO task at the scale midpoint with respect to task analyzability. Thus, subjects perceived the APO task to be roughly halfway between unanalyzable and highly analyzable. With respect to the dimension of ambiguity, again subjects rated the APO task around the scale midpoint, roughly halfway between highly ambiguous and unambiguous. Thus, overall, subjects did not find the APO task as complex as had been anticipated. It was observed that the APO task focuses subjects on automating the current system and does not encourage looking at entirely new functions or opportunities the technology might provide. This lack of complexity is one plausible explanation for why the structured problem-solving approach did not result in any significant differences.

Study Limitations

System Limitations

One limitation of this study has to do with shortcomings of EIES 2 at the time of this study (the 1993–94 academic year). Access to EIES 2 can be very difficult in the evening during the peak hours of 7:00 to 11:00 P.M. Numerous complaints were received about subjects' inability to connect onto the system. In addition, the current default text editor on EIES 2 is a line editor, rather than a full screen editor, which can be very frustrating to use. EIES 2 is menu and command driven and has no graphical user interface with which most subjects would be more comfortable. (There is currently a graphical interface through the World Wide Web on the Internet utilizing HTML browsers such as Netscape.) These shortcomings, we hope, have already been or will be resolved in the near future, and replications of the distributed asynchronous conditions with improved system features and access might well result in significantly better quality.

Methodological Limitations

By the very nature of the process, it is impossible to assure full control of the behavior of distributed asynchronous groups. The group members could ignore the instructions limiting their communication. However, direct questioning of FtF groups during debriefing, and daily observation of the CC groups did not indicate any evidence of circumventing the experimental manipulation. One design limitation was that we did not explore the relative effectiveness of different modes of designating a leader or motivating and defining the leader's role. Because the "leaders" in this experiment had only a very limited role, we do not think it would make much difference whether they volunteered or were elected or appointed. Another design limitation concerns the fact that the FtF groups had a two-week lapse between sessions. Although we designed the experiment to control for elapsed time, perhaps the time gap between FtF meetings, rather than the use of technology, caused a large portion of the difference between the FtF and CC conditions. We do not feel that elapsed time thwarted the efforts of FtF groups, owing to the concept that reflection or incubation of ideas [63] requires time.

Distribution of IS Majors

The uneven distribution of IS majors across experimental treatments necessitated that we use an analysis of covariance model for statistical methods. Use of covariance results in greater difficulty in reaching significant differences between treatments. More care in the composition of experimental cells would have allowed a straight ANOVA to be run and could perhaps have resulted in more significant results regarding quality.

Theoretical Model

Only the output variables of quality and creativity were measured. All other components of the theoretical model—input variables and interaction variables—were not measured. These "black box" variables need to be studied and their effects measured to determine more clearly why creativity was so pronounced in asynchronous groups.

Approach to Rating Quality

Although the instrument used by the panel of expert judges to rate each group's quality was developed by Olson et al. [50] after extensive investigation of software development professionals and academicians, perhaps there is a more thorough and precise method to accomplish this rating activity. Another plausible method to use for expert judges to rate quality would be for someone (e.g., the investigator) first to devise a complete list of items obtained from all groups' requirements definition reports. This list of items would be obtained from the discussion of functionality as contained in each group's report. After this list of items is devised, the panel of expert judges could be convened to discuss which items they consider the most important with respect to the quality of the requirements definition. Then a revised list of these top ten to twelve items could be used by the expert panel to judge the quality of each group's requirements definition document. This method of judging should reduce subjectiveness and also increase the interrater reliability among the expert judges.

Task Complexity and Creativity

The APO task used in this study seemed to lack complexity. The task also appeared to focus groups' idea generation and development narrowly. On numerous occasions, the facilitator witnessed groups discarding creative and innovative ideas, referring to the direction provided from the APO task statement. If one is interested in studying various structured group problem-solving approaches, and/or in studying group creativity, a more complex and open-ended task might be more appropriate. However, the APO task is a "good" task in that subjects appeared to enjoy working on it (as evidenced by only one subject out of 215 not completing the experiment).

Future Research

Additional communication conditions would strengthen our ability to draw conclusions. For instance, FtF groups were restricted from communicating with one another outside of the two meetings. Allowing these groups to communicate via the telephone would afford them the opportunity to stay connected throughout the experiment, and thus make this treatment more realistic. Also, a synchronous CC condition would allow comparisons of the impact of technology while isolating the factors of time and distance. With the inclusion of this treatment, we could conclude more definitively whether distributed asynchronous communication fosters creativity, rather than computer-mediated communication in general.

Before we discard the structured approach as ineffective, a second, more equivocal and complex task is worthy of exploration. The task should be truly ill structured and heuristic so that no solution path is easily evident.

The theoretical framework needs to be empirically tested and refined. It is necessary to get a "footprint" of creative groups through content coding and analysis. For each CC dependent variable from Table 1, group transcripts need to be content-coded. This will enable comparison among creative groups, and between creative and uncreative groups. Also, each dependent variable should also be measured through means of subject self-report. For each experimental subject, individual creativity should be measured. Likewise, each group should be scored regarding the degree of homogeneity/heterogeneity. Although it is theoretically possible to control for these variables (creativity and heterogeneity), it is not practical. By obtaining measures for these variables, they can be used as covariates during data analysis. Also, when one is testing aspects of the minority influence framework, it is probably not advisable to assign a group leader but rather to let a leader emerge.

Although further investigation remains to be accomplished, this study provides a firm foundation from which to examine the relationship among mode of communication, creativity, and quality for upstream development activities.

REFERENCES

1. Adrianson, L., and Hjelmquist, E. Group processes in face-to-face and computer-mediated communication. *Behavior and Information Technology*, *10*, 4 (1991), 281–296.

2. Amabile, T.M. The social psychology of creativity: a componential conceptualization. *Journal of Personality and Social Psychology*, *45*, 2 (1983), 357–376.

3. Arunachalam, V. Computer-mediated communication and structure interaction in transfer pricing negotiation. *Journal of Information Systems* (1994).

4. Boehm, B.W. *Software Engineering Economics*. Englewood Cliffs, NJ: Prentice-Hall, 1981.

5. Burke, K., and Chidambaram, L. Development in electronically-supported groups, a preliminary longitudinal study of distributed and face-to-face meetings. *Proceedings of the Twenty-Seventh Annual Hawaii International Conference on System Sciences*, IV, 1994, pp. 104–113.

6. Canning, R. 1977. Getting the requirements right. *EDP Analyzer*, *15*, 7 (1977), 1–13.

7. Clapper, D.L.; McLean, E.R.; and Watson, R.T. An experimental investigation of the effect of a group decision support system on normative influence in small groups. *Proceedings of the Twelfth ICIS*, 1991, pp. 273–282.

8. Conklin, J., and Burgess Yakemovic, K.C. Process-oriented design rationale. *Human-Computer Interaction*, *6*, 3–4 (1991), 357–391.

9. Couger, J.D.; Higgins, L.F.; and McIntyre, S.C. (Un)structured creativity in information systems organizations. *MIS Quarterly* (December 1993), 375–397.

10. Curtis, B.; Krasner, H.; and Iscoe, N. A field study of the software design process for large systems. *Communications of the ACM*, *31* (1988), 1268–1287.

11. Daft, R.L., and Lengel, R.H. Organizational information requirements, media richness and structural design. *Management Science*, *32*, 5 (1986), 554–571.

12. Daly, B. 1993. The influence of face-to-face versus computer-mediated communication

channels on collective induction. *Accounting, Management and Information Technology, 3*, 1 (1993), 1–22.

13. Daniels, Jr., R.M.; Dennis, A.R.; Hayes, G.; Nunamaker, J.F.; and Valacich, J. Enterprise analyzer: electronic support for group requirements elicitation. *Proceedings of the Twenty-fourth Hawaii International Conference on System Sciences, 3* (1991), 43–52.

14. Dubrovsky, V.J.; Kiesler, S.; and Sethna, B.N. The equalization phenomena: status effects in computer-mediated and face-to-face decision making groups. *Journal of Human-Computer Interaction, 6* (1991), 119–146.

15. Dufner, D.; Hiltz, S.; and Turoff, M. A preliminary analysis of the effects of the use of voting tools and sequential processing. *Proceedings of the Twenty-Seventh Hawaii International Conference on System Sciences, 4* (1994), 114–123.

16. Duncan, N., and Paradice, D. Creativity in GDSS: an integration of creativity, group dynamics, and problem-solving theory. *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences, 4* (1992), 277–287.

17. Dunn, R. *Software Defect Removal*. New York: MacGraw-Hill, 1984.

18. Eveland, J.D., and Bikson, T.K. Work group structures and computer support: a field experiment. *ACM Transactions on Office Information Systems, 6*, 4 (1989), 354–379.

19. Finholt, T.; Sproull, L.; and Kiesler, S. Communication and performance in ad hoc groups. In J. Galegher, R. Kraut, and C. Egido (eds.), *Intellectual Teamwork: Social and Technological Foundation of Cooperative Work*. Hillsdale, NJ: Lawrence Erlbaum, 1990.

20. Galegher, J., and Kraut, R. Computer-mediated communication for intellectual team-work: a field experiment in group writing. *Proceedings of CSCW 90* (November 1990), 65–78.

21. Galletta, D.F.; Sampler, J.L.; and Teng, T.C. Strategies for integrating creativity principles into the system development process. *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences*, 4, 1992, pp. 268–276.

22. Gallupe, R.B.; Bastianutti, L.M.; and Cooper, W.H. Unblocking brainstorms. *Journal of Applied Psychology, 76*, 1 (1991), 137–142.

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

24. Gallupe, R.B.; DeSanctis, G.; and Dickson, G.W. Computer-based support for group problem-finding: an experimental investigation. *MIS Quarterly* (1988), 277–296.

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

26. George, J.F.; Easton, G.K.; Nunamaker, J.F.; and Northcraft, G.B. A study of collaborative group work with and without computer-based support. *Information Systems Research, 1*, 4 (1990), 394–415.

27. Glass, R., and Vessey, I. Software tasks: intellectual, clerical . . . or creative? *Proceedings of the Twenty-Seventh Hawaii International Conference on System Sciences*, 4, 1994, pp. 377–382.

28. Hackman, J.R., and Morris, C.G. Group tasks, group interaction processes, and group performance effectiveness: A review and proposed integration. In L. Berkowitz (ed.), *Advances in Experimental Social Psychology*, vol. 8. New York: Academic Press, 1975, pp. 47–99.

29. Hiltz, S.; Dufner, D.; Holmes, M.; and Poole, S. Distributed group support systems: social dynamics and design dilemmas. *Journal of Organizational Computing, 2*, 1 (1991), 135–159.

30. Hiltz, S.; Johnson, K.; and Turoff, M. Experiments in group decision making, 1: communications process and outcome in face-to-face versus computerized conferences. *Human Communication Research, 13*, 2 (1986), 225–252.

31. Hiltz, S., and Turoff, M. *The Network Nation*. Cambridge, MA: MIT Press, 1993.

32. Ho, T.H., and Raman, K.S. The effect of GDSS and elected leadership on small group meetings. *Journal of Management Information Systems, 8*, 2 (1991), 109–133.

33. Janis, I.L. *Groupthink*, 2d ed. Boston: Houghton Mifflin, 1982.

34. Jarvenpaa, S.; Rao, R.; and Huber, G. Computer support for meetings of medium-sized groups working on unstructured problems: a field experiment. *MIS Quarterly, 12* (1988), 645–665.

35. Kiesler, S.; Siegel, J.; and McGuire, T.W. Social psychological aspects of computer-

mediated communication. *American Psychologist, 39*, 10 (1984), 1123–1134.

36. King, N., and Anderson, N. Innovation in working groups. In M.A. West and J.L. Farr (eds.), *Innovation and Creativity at Work.* Chichester, UK: Wiley and Sons, 1990.

37. Kunz, W., and Rittel, H. Issues as elements of information systems. Working paper no. 131, Institute of Urban and Regional Development, University of California at Berkeley, 1970.

38. MacLean, A.; Young, R.; Bellotti, V.; and Moran, T. 1991. Questions, options, and criteria: elements of design space analysis. *Human-Computer Interaction, 6*, 4 (1991), 201–250.

39. Malone, T., and Crowston, K. What is coordination theory and how can it help design cooperative work systems? *CSCW 90 Proceedings*, 1990, pp. 357–370.

40. McGrath, J. *Groups: Interaction and Performance*, Englewood Cliffs, NJ: Prentice-Hall, 1984.

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

42. McLeod, P.L., and Elston, S.E. Minority opinion and private opinion change: moderating effects of GSS use and anonymity. Paper presented at Academy of Management Meeting, 1994.

43. Miranda, S.M., and Bostrom, R.P. The impact of group support systems on group conflict and conflict management. *Journal of Management Information Systems, 10*, 3 (1993–94), 63–95.

44. Myers, W. MCC, planning the revolution in software. *IEEE Software* (1985).

45. Nemeth, C.J. Differential contributions of majority and minority influence. *Psychological Review, 94* (1986), 23–32.

46. Nemeth, C.J., and Chiles, C. Modeling courage: the role of dissent in fostering independence. *European Journal of Social Psychology, 18* (1988), 275–280.

47. Nemeth, C.J., and Kwan, J. Minority influence, divergent thinking, and the detection of correct solutions. *Journal of Applied Social Psychology, 17* (1987), 788–799.

48. Nemeth, C.J., and Wachtler, J. Creative problem solving as a result of majority versus minority influence. *European Journal of Social Psychology, 13* (1983), 45–55.

49. Olson, G.M., and Olson, J.S. User-centered design of collaboration technology. *Journal of Organizational Computing, 1* (1991), 61–83.

50. Olson, G.M.; Olson, J.S.; Carter, M.; and Storrosten, M. Small group design meetings: an analysis of collaboration. *Human Computer Interaction, 7*, 4 (1992), 347–374.

51. Olson, J.S.; Olson, G.M.; Storrosten, M.; and Carter, M. Groupwork close up: a comparison of the group design process with and without a simple group editor. *ACM Transactions on Office Information Systems, 11*, 4 (1993), 321–348.

52. Poole, M.S.; Holmes, M.; Watson, R.; and DeSanctis, G. Group decision support systems and group communication. *Communication Research, 20*, 2 (1993), 176–213.

53. Rao, V.S., and Jarvenpaa, S.L. Computer support of groups: theory-based models for GDSS research. *Management Science, 37* (1991), 1347–1362.

54. Siegel, J.; Dubrovsky, V.; Kiesler, S.; and McGuire, T. Group processes in computer-mediated communication. *Organizational Behavior and Human Decision Processes, 37* (1986), 157–187.

55. Smith, J.Y., and Vanecek, M.T. Dispersed group decision making using nonsimultaneous computer conferencing: a report of research. *Journal of Management Information Systems, 7*, 2 (1990), 71–92.

56. Soloway, E. What to do next, meeting the challenge of programming-in-the-large. In E. Soloway and S. Iyengar (eds.), *Empirical Studies of Programmers.* Norwood, NJ: Ablex, 1986.

57. Sproull, L., and Kiesler, S. Reducing social context cues: electronic mail in organizational communication. *Management Science, 32*, 11 (1986), 1492–1512.

58. Steiner, I.V. *Group Process and Productivity.* New York: Academic Press, 1972.

59. Telem, M. Information requirements specification brainstorming collective decision-making approach. *Information Processing and Management, 24*, 5 (1988), 549–566.

60. Turoff, M. Computer-mediated-communication requirements for group support. *Journal of Organizational Computing, 1*, 1 (1991), 85–113.

61. Venkatesh, M., and Wynne, B.E. Effects of problem formulation and process structures on performance and perceptions in a GDSS environment: an experiment. *Proceedings of the Twenty-Fourth Hawaii International Conference on System Sciences*, 4, 1991.

62. Vessey, I., and Conger, S. Learning to specify information requirements. *Journal of Management Information Systems, 10*, 2 (1993), 177–201.

63. Wallas, G. *The Art of Thought.* New York: Harcourt, Brace and World, 1926.
64. Walz, D.B.; Elam, J.J.; and Curtis, B. Inside a software design team, knowledge acquisition, sharing and integration. *Communications of the ACM, 36*, 10 (1993), 63–77.
65. Watson, R.T.; DeSanctis, G.; and Poole, M.S. Using a GDSS to facilitate group consensus: some intended and unintended consequences. *MIS Quarterly* (1988), 463–477.
66. Weisband, S. Group discussion and first advocacy effects in computer-mediated and face-to-face decision making groups. *Organizational Behavior and Human Decision Processes, 53* (1992), 352–380.
67. West, M.A. The social psychology of innovation in groups. In M.A. West and J.L. Farr (eds.), *Innovation and Creativity at Work.* Chichester, UK: Wiley and Sons, 1990.
68. Wood, J.G., and Nosek, J.T. Discrimination of structure and technology in a group support system: the role of process complexity. *Proceedings of ICIS,* 1994, pp. 187–199.
69. Woodman, R.; Sawyer, J.; and Griffin, R. Toward a theory of organizational creativity. *Academy of Management Review, 18*, 2 (1993), 292–321.
70. Yakemovic, K.C.B., and Conklin, E.J. Report on a development project use of an issue-based information system. *CSCW 90 Proceedings*, 1990, pp. 105–118.
71. Zigurs, I.; Poole, M.S.; and DeSanctis, G.L. A study of influence in computer-mediated group decision making. *MIS Quarterly* (1988), 625–644.