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An Experimental Analysis of Face to Face versus Computer Mediated Communication Channels

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Abstract

Experimental research on Group Decision Support Systems (GDSS) has generally focused on democratic groups whose members typically share the same objectives. In organizations, however, there are many situations where groups have a leader who has the power to override the group's recommendation, the objective of the leader may not be the same as the objective of each member, and not everyone may have the same information. This paper reports the results of an experiment in which the groups, having a designated leader, worked on a mixed-motive task. Within this context, we analyze group decision outcomes and processes for groups that use a face-to-face channel of communication and those that utilize computer mediated communication. We compare performance of the leader and members with respect to an objective measure of performance, the efficient frontier. The results indicate that for this task groups using face-to-face channel outperform groups using computer mediated communication.

Key words: GDSS, efficient frontier, computer mediated communication, group leader, information richness

1. Introduction

In most modern organizations key business decisions are often made by small groups. These decisions can either be made in a face-to-face (FTF) setting or in a distributed setting where group members interact even though they are stationed in different locations. In the latter case, interaction can occur in a number of ways: talking to each other over a speaker phone, teleconferencing via a TV monitor or computer screen or simply exchanging electronic mail messages. The use of computers for communication is increasingly becoming common,

especially with the advent of telecommuting and the concept of a virtual organization (Biocca, Kim, and Levy 1995). In a virtual organization, face-to-face communication may be replaced by computer mediated communication.

The ramifications of the computer mediated communication (CMC) on decision making is not well understood. In studying the effects of CMC, one needs to address the type of group as well as the type of tasks that are performed by the groups (McGrath 1984). In general, a group can be a democratic group or one run by a designated leader. Democratic groups are those in which no single individual is designated as the group leader. In such groups, all group members are expected to contribute and the final group decision is based on some voting procedure (e.g. majority rule, consensus). In groups with a designated leader, the leader has the authority to make the final decision despite the preferences of some, or all, of the other group members. (As Abraham Lincoln is reported to have once exclaimed at a cabinet meeting: "The Vote is 12 'nay's' to one 'aye'; the 'aye's have it").

Many groups within organizations have a leader in charge. The impact of computer mediated communication on such groups is not well understood. Does leadership work the same way in distributed groups that use CMC as it does in FTF groups? Prior work has not addressed this issue when the group is faced with a mixed-motive task. For other types of tasks, the reader is referred to Feltz , Johnson, and Turoff 1991; Lee 1991; Lim, Raman, and Wei 1990, 1994; Zigrus, Poole, and DeSanctis 1988.

The leader and the other group members may have different roles and incentives. In a typical organizational setting, the role of the leader is to protect the overall interests of the organization and his (her) reward is tied to the organization's profits. The role of other members, however, might be to defend their narrower departmental interests and their rewards are often tied to the performance of their department. Not all members may have the same information (information asymmetry). Groups often confront complex tasks that involve uncertainty and equivocality.

The objective conflicts may result in competition and information asymmetry may require cooperation. Members need to cooperate to exchange information and reduce uncertainty and equivocality. The dual motives (competition and cooperation) result in a mixed-motive task.

We designed a mixed-motive task in the form of a production planning problem. A company manufactures four products and receives orders for these products from its customers. Each order consists of some combination of the four products. The group meets to decide which orders to fill subject to capacity constraints. Each member of the group represents a different business function (e.g. marketing, production, purchasing). Each business function is given the costs to fill the orders. Each member can have a personal objective that differs from the organization and the other group members. Under these conditions, finding a solution that is acceptable to all members requires the group to work on a task that contains both ambiguity and equivocality.

2. Background

2.1. GDSS and communication channels

Media Richness Theory (MRT), proposed by Daft and Lengel (1984, 1986), asserts that one should choose a communication medium that matches features of the task. They identified two key features of tasks: degree of uncertainty and degree of equivocality. They classified communication media along a continuum of low to high "richness" using four criteria: feedback, multiple cues, language variety, and personal focus. For example, FTF groups have a richer media than CMC groups as they may use verbal communication enriched by facial cues to convey information[1] and relay quick feedback to other parties. MRT proposes that FTF media is preferred for messages containing equivocality (ambiguity) while written or computer mediated media is used for unequivocal messages.

McGrath and Hollingshead (1993), utilizing MRT (Daft and Lengel 1984, 1986) propose a task and medium fit matrix based on information richness of the media and the information requirements of the task. As information richness decreases in the case of CMC groups, McGrath and Hollingshead argue that it forms a poor fit for mixed-motive tasks that involve negotiation. Within the context of McGrath and Hollingshead's conjecture, much of the prior work that has been done has focused on idea generation or preference tasks.

Raman, Tan, and Wei (1993) investigated the effect of GDSS and communication medium for two types of tasks, intellective and preference tasks. The outcome variables include decision satisfaction, and consensus change (a measure of the ability of a group to resolve conflicts and reach a decision), and a surrogate for decision confidence. Contrary to McGrath and Hollingshead's conjecture, the researchers found no difference in outcome variables between the FTF and the CMC groups for intellective tasks. However, the FTF groups performing the preference task had a higher decision satisfaction and confidence, and showed higher consensus change than their CMC counterparts, supporting McGrath and Hollingshead's conjecture that CMC provides a poor fit for preference tasks. In a study on an idea generation type task, Burke and Chidambaram (1995) found that the performance (quality of outputs) did not differ between FTF groups and CMC groups leading them to question the validity of the media richness theory.

The literature on the effect of communication channels on mixed-motive tasks is limited. For democratic groups performing a negotiation task, McGrath and Hollingshead's conjecture that FTF communication provides a better fit is supported (Rhee et al. 1995). In another study, Straus, and McGrath (1994) test the effect of media on the degree of task interdependence and find that tasks that require significant amount of coordination require richer media. They find that members in the CMC groups have more difficulty understanding one another than do members in the FTF groups. In addition, they argue that advanced information technology to support CMC groups may redistribute power among the members in ways that are inconsistent with traditional lines of authority.

In addition to communication media, factors such as task complexity and GDSS features also tend to affect the results of studies focusing on communication media. Gallupe and McKeen (1990) addressed the research question: "How does GDSS affect group decision making for choice tasks where group members are either face-to-face or remote?" In their

study, the task was to rank causes for declining profits of a simulated company, and the decision quality was measured using a benchmark decision made by three experts. The results indicated no difference between any of the experimental conditions. One reason for this, as pointed out by the authors, is that perhaps the task was not difficult enough to require a GDSS.

The GDSS features available to decision makers should be compatible with the requirements of the task. Although many studies, for example, Sharda, Barr, and McDonnell (1988) find the use of a GDSS to be associated with improved decision process and outcomes, others find no differences between groups that use a GDSS and those that do not (e.g. Ruble 1984). Ruble suggests that the lack of difference may be due to the unavailability of specific features to properly support the group decision making process or the nature of the task (e.g. a simple task) contributes to the lack of differences between groups.

Based on Daft and Lengel's (1984) suggestion that a laboratory situation which resembles the ambiguity faced by managers in organizations should provide subjects with partial or contradictory views, the experimental task in this study involves uncertainty, equivocality, and complexity. Although complexity is not the main variable of this study, we designed a task that was complex and required decision support[2] both to eliminate the problem that Gallupe and McKeen (1990) and Ruble (1984) had in their study as well as to approximate real life situations. Both FTF and CMC groups have access to the same GDSS. The effect of communication media is studied within this GDSS supported setting to experimentally evaluate McGrath and Hollingshead's (1993) conjecture that the FTF media is a better fit for mixed-motive tasks. The impact of communication channel (FTF versus CMC) on group member and leader is studied with respect to performance, truthfulness of information exchange, performance expectation, performance variability, frustration with the process, and the efficiency of problem solving.

3. Research questions and hypotheses

In this study we address the following research question: does computer mediated communication significantly affect the decision process and outcomes of a leader-directed group faced with a mixed-motive task.

The mixed-motive task requires the three managers and the leader to agree on a set of orders to produce. The different orders have a different payoff for each of the group members. Each group member has private information about his/her costs with respect to fulfilling each order. Hence, consistent with many real-world scenarios, we simulate a situation where each member attempts to maximize his/her departmental profit while the leader tries to maximize organizational profit. Although the leader has the authority to override member solutions, his (her) ability to make "good" decisions is limited by the information provided by the members in his (her) group. Additionally, because the group members have some group history and need to function effectively as a group after this experiment, the leader may not be willing to make decisions that are detrimental to any group member. However, this effect may be somewhat mitigated in the CMC environment, where factors such as de-individuation (Festinger, Pepitone, and Newcomb

1952; Zimbardo 1969) and social presence (Short, Williams, and Christi 1976) may become important.

Computer mediated communication, by reducing the number of channels that are used for personal interaction, may promote de-individuation. De-individuation is defined as the process whereby submergence in a group produces loss of identity for the individuals. The member's obligations to the group norms often leads to the weakening of social norms by relaxing social constraints on the individual (Festinger, Pepitone, Newcombe 1952; Zimbardo 1969). The results of de-individuation include reduced fear and guilt, diminished concern for personal standards of judgement and morality, and reduced sense of responsibility for one's actions (Prentice-Dunn and Rogers 1989).

De-individuation may not be unrelated to social presence. Short, Williams, and Christie (1976) define 'Social Presence' as the quality of the communication medium. They suggest that Social Presence will affect the way individuals perceive their discussions, and their relationships with others. They hypothesize that communications media vary in their degree of Social Presence. Also, people tend to avoid using a media with low Social Presence for interactions that they perceive to need a medium with higher social presence. Social Presence is a single dimension that is the aggregation and the cognitive synthesis of such factors that include physical appearance and posture, facial expression, direction of looking, mutual gaze and the feeling of intimacy and trust as perceived by the individual to be present in the medium. Low Social Presence is characterized as unsociable, insensitive, cold, and impersonal. Research seems to indicate that FTF channel is highest in Social Presence followed by video, multichannel audio, speaker phone, and written text (Short, Williams, and Christie 1976, pp. 68–72). Social Presence was found to be significantly higher in visual than in non-visual media. Much of the non-verbal and verbal communication cues which form a normal part of FTF interaction are filtered in a CMC environment resulting in lower Social Presence. FTF contact seems to be necessary for conflict resolution, and the development of trust (Westrum, 1972). Low social presence generally improves performance of idea generation tasks. It makes it possible for the individuals to offer both popular and unpopular ideas potentially resulting in an improved set of ideas. However, the impact low social presence on negotiation tasks may not be positive.

3.1. Group performance

Communication theory (Shannon and Weaver 1949) predicts that when decision makers have a higher number of alternative communication media, information loss is decreased, resulting in higher effectiveness of communication and improved performance. This suggests that the FTF groups should perform better than the CMC groups.

McGrath and Hollingshead (1993) argue that mixed-motive tasks require a rich communication media. Hence, CMC media that does not provide the communication media richness of the FTF approach would be a poor fit for negotiation tasks. Since member rewards are essentially based on convincing the leader to choose a production plan favorable to him (her) we hypothesize that members in FTF groups will be more effective in doing so. FTF media provides a higher degree of social presence (Short, Williams, and Christie 1976)

and has been found to improve conflict resolution and development of trust (Westrum 1972). Hence, based on the media richness theory of Daft and Lengel (1986), McGrath and Hollingshead's (1993) conjecture, and the effect of social presence (Short, Williams, and Christie 1972) we propose that:

H1: For groups with a designated leader and a mixed-motive task, member performance of the FTF groups will be higher than for CMC groups.

Several factors affect the leader's ability to select a solution. A leader has some estimate of departmental information (e.g. standard costs from a cost accounting system) and based on such estimates he (she) already has a lower bound on his (her) performance. The issue, therefore, becomes to what extent the leader can improve his (her) solution beyond the lower bound. In arriving at a solution, three factors become critical. The first factor is the quality of the information that he (she) obtains from the managers. Given the rich media associated with the FTF approach, one expects that the leader will be better able to obtain accurate information and thus make a better decision. Second, the leader cannot completely ignore the group member's recommendations as they have some group history and have to work together in the future. Hence, the leader's final solution is likely to be influenced by the members' recommendations. This implies that the leader may be willing to choose a solution that would result in an equitable payoff between the members provided that it has little or no cost to him (her). Third, in the case of CMC groups, low social presence plays two roles. As a result of low social presence the leader may be willing to make decisions that are favorable to him (her) at the expense of the members since he (she) does not have to face the members to communicate his (her) unilateral decision. However, we believe this effect will be mitigated by the group's history. As a result of low social presence, that is characterized as insensitive, cold, and impersonal, the members may not be completely honest when reporting their departmental information to the leader. This would in effect result in the leader making choices that could negatively impact his/her performance. Hence we propose the following hypothesis:

H2: Leader performance for FTF groups will be higher than that for CMC groups.

3.2 Truthfulness of information exchange

The members, possessing accurate information about their departments, should be able to gauge their own performance. Leader performance, however, depends on the members' performance. Hence, a leader can gauge his (her) performance only as accurately as he (she) is able to gauge information about the departments. The members may have an incentive to provide misinformation and bias the leader's perception about some solutions.[3] As a result of low social presence in CMC groups, and the fact that the members don't have to face the leader when they are untruthful, the tendency to be untruthful may be higher in the CMC groups than in the FTF groups. Low social presence may make negotiators less sensitive to

other points of view making it easier for members in CMC groups to act in their own self-interest. The reduced social presence may make members less sensitive to the leader's need to receive accurate information resulting in the leader receiving less accurate data from members in the CMC groups than in the FTF groups. Short, Williams, and Christie (1976) describe that whenever the nature of communication requires the individuals to constantly assess each other's reactions, to assess accurately the 'atmosphere' of the meeting, to be on guard against allowing personal conflicts to break up the meeting, to be sensitive to personal feelings of the group members, then a medium high in Social Presence is preferred. Westrum (1972) reports that FTF contact is critical for the development of trust and truthfulness. The leader may try to gauge the accuracy of the information that he/she receives. The leader is expected to be able to more effectively do this with a FTF media that has higher richness, and higher Social Presence than the CMC media.[4] Hence, we propose the following hypothesis:

H3: The members in the FTF group will reveal their departmental information to the leader more truthfully than the members in the CMC groups.

3.3. Performance expectations

Leader's expected performance (perception of performance) matches his (her) realized performance (actual performance) if the members communicate accurate departmental information to him (her). The FTF medium is a rich communication channel and thus information exchange is facilitated. Furthermore, as discussed before, the effects of low social presence in the CMC groups may magnify untruthfulness. Leaders, hence, may have a better estimate of each department's information in FTF groups than in CMC groups. This would imply that in the final solution adopted, the leader's perceived performance should be closer to his/her actual performance in FTF groups than in CMC groups. This suggests the following hypothesis:

H4: The difference between the Leader's perceived and actual performance will be larger in CMC groups than in FTF groups.

Siegel et al. (1986) suggest that groups communicating electronically exhibit more antisocial behavior and tend to make more extreme decisions. We expect that in the FTF groups, the leader will try to be fair to all members and attempt to assure members receive comparable payoffs. The lower social presence in CMC groups may make the leader less concerned about achieving a solution that assures comparable outcomes for all members. In other words, the variance among member performance should be smaller in FTF groups than in CMC groups. Thus, we propose the following hypothesis:

H5: In the final solution adopted, the variance among member performance will be smaller in FTF groups than in CMC groups.

3.4. Frustration with the process

For a mixed-motive task, McGrath and Hollingshead (Rhee et al. 1995) and Daft and Lengel (1984, 1986) suggest that electronic communication channels are restrictive, with respect to the richness they provide and hence are not a good fit for tasks that involve equivocality and negotiation, compared to FTF channels. An electronic channel delays feedback and filters the cues that can be conveyed in face-to-face or verbal communication. Prior research has reported lower frustration with the process in FTF groups than in CMC groups (Rhee et al. 1995). Members that have to negotiate may feel frustrated with the process in a constrained communication environment. Also, since social presence is lower, the CMC groups may foster the view of negotiation as an unsociable, insensitive, and cold that could result in developing a win-lose orientation. These could lead to higher frustration. We thus propose that:

H6a: Member frustration with the process will be lower in FTF groups than in CMC groups.

There are two opposing factors at work as far as leaders are concerned. The restrictiveness of the communication media for the CMC groups can be frustrating for the leader when he (she) is attempting to obtain information. However, when it comes time to make a decision, it will be easier for the leader in a CMC group to make an unpopular decision as he (she) does not have to immediately face his (her) group members. As pointed out earlier, this second effect is tempered by the fact that the groups do have some history and are expected to work together in the future. Therefore, we expect the leader to work with the members to find a solution rather than to unilaterally override their solution. Thus, we do not expect the distributed communication, which may make it easier for the leader to override member solutions, to affect the leader's level of frustration as much as the communication restriction that is imposed on him (her). Thus, we propose:

H6b: Leader frustration with the process will be lower in FTF groups than in CMC groups.

3.5. Problem-solving efficiency

To test problem-solving efficiency, we study the time to converge to a solution. It has been shown that it takes longer for CMC groups to reach a solution than for FTF groups (Rhee et al. 1995). Communication in CMC groups may be more restrictive and less efficient leading to longer time duration to reach a decision than in FTF groups. Since in our study the leader can impose solutions on the group, it is possible that in the CMC case, once the leader is satisfied with a solution, he (she) imposes this solution on the group and terminates the negotiation session. However, as mentioned earlier the need to find an equitable solution may preclude the leader from doing this. Furthermore, in the CMC case the leader may not be able to obtain satisfactory information easily, requiring additional time in obtaining information. Hence we propose that:

H7: The time to converge to a solution will be longer for CMC groups than for FTF groups.

4. The experiment

Twelve four member groups were randomly assigned to each of the two experimental conditions. The independent variable was the communication channel (FTF versus CMC) used by participants within the experimental setting.

4.1. The task

The task used in this experiment is a production planning problem. The company makes four products. Each customer order consists of some combination of all four products. The customers have placed twenty orders. The problem is to decide which orders to fill to maximize reward without violating product capacity constraints. An order is to be filled completely or not at all. No partial orders can be filled. Associated with each order is a total revenue. The cost of filling an order is different for each department so that one order that is favorable to one department or the leader may not be desirable by others.

4.1.1. Member reward and hidden costs

Typical of many organizational incentive mechanisms, member bonus is determined by how well each department controls its *Actual Departmental Costs (ADC)* compared to *Projected Costs (PC). A* department receives a bonus that is equal to a percentage (To create a specific example, without loss of generality, this percentage is set equal to sixty percent for this experiment) of the difference between the *ADCs* and PCs. To lower the *ADCs* in an attempt to maximize bonus, each department incurs some hidden costs that are not compensated by the organization, the *Uncompensated Departmental Effort Costs* (UDEC). The UDEC can be viewed as a monetary specification of the intangible costs associated with higher stress resulting from tighter schedules, more intense workload, etc. For each order selected, the internalized reward for each departmental manager is equal to the bonus he (she) receives (this is a proxy for the compensation of the department), minus the costs the department incurs for increased effort. Figure 1 represents a sample of the relationships between different costs, bonus, and reward. The horizontal axis represents the effort level and the vertical axis represents the units to measure costs and reward. *As* a member increases his (her) effort level, the ADC decreases and hence the deviation between ADC and PC widens resulting in a higher bonus. However, because increased effort is associated with increased UDEC, the reward, i.e., the bonus minus the UDEC is not necessarily an increasing function of effort level. The figure shows that from the perspective of each member, there exists an optimal effort level for each order. The optimal effort level occurs either at the point where the slope of the concave reward curve is zero, or at one of the extremes of effort levels.

Instead of providing the subjects with the functions similar to those shown in figure 1, we select four random points on the effort axis and provide the corresponding values for all functions at those points as legitimate options for the effort levels. This is to avoid overly complicating the problem.

With this incentive mechanism, utility theory predicts that each member will select effort at a level where the marginal increase in bonus is equal to the marginal cost of extra effort.

Thus, each member has to make two decisions. One decision is which orders to select and another is what effort levels to expend on each order? The problem, therefore, can be divided into two separate sub-problems. Once optimal effort levels are selected for each order, the optimal ADC and UDEC, (ADC*) and (UDEC*) respectively, will be used to solve the second subproblem of selecting a subset of the orders. The mathematical models are provided in Appendix 1.

4.2. Leader incentive

The leader tries to maximize the organizational profit as his (her) reward is directly tied to organizational profit. The organizational profit generated by each order selected is the revenue minus the sum of the ADCs incurred at the three departments. The leader receives a percentage (for this experiment without loss of generality this percentage is set equal to 9%) of the organizational profit as reward. The leader's problem is captured by the model in appendix 1.

The leader has the authority to impose his (her) solution on the managers. The ADC's are local information at the departmental level and the leader originally has only an estimate of the departmental costs for filling an order, i.e. the Projected Cost (PC). The leader uses these costs as the initial values of ADCS. The department managers may send the leader updated information about their ADCs corresponding to the level of effort they select. The reward for each member is computed by substituting the solution – a set of orders – adopted by the group into their objective function. Because the objective of each participant is to maximize his/her individual reward, the higher the value of the objective function, the better will be the individual's performance.

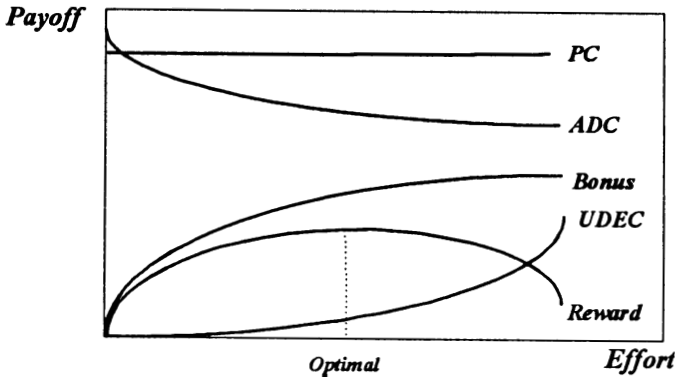

Figure 1: Optimal effort where slope of reward is zero.

4.3. Subjects

Forty eight junior and senior undergraduate business students enrolled in a business decision-making course served as subjects for the experiment. Solution of a case that involved solving the type of problem described above was a course requirement and an integral part of the course. Students were required to work in "management teams" to solve the problem.

Fifteen percent of the course grade was allocated for the experiment. Each Student's grade for the experiment was directly proportional to the reward points he/she received on the exercise. Each subject could use the optimization capability of the GDSS to find the optimal solution from his/her perspective. This value is an estimate of the number of reward points that could be received on the exercise and it was used as a measure of performance. Once the group agreed on a solution, the objective function value that each achieved was compared against those achieved by others in the same treatment condition. Then the highest received 15% and the others received a percentage of 15% that was proportional to the percentage of the value of the highest. This way, we operationalized an incentive system that encouraged students to try to maximize their points so that they get to 15% or very close to it. Hence, students linked the points on the experiment to 15% of their grade.

We conducted the experiment early in the term. Completion of the experiment was the first component for which a grade was earned by the students. Consequently, students had no grade "cushion" which might lead to their not treating the experiment seriously. The grade on this experiment was a substantive contributor to the student's final grade. It provided strong motivation to do well in the experiment.

Each student was randomly assigned to either a FTF or a CMC group. The groups were formed the first week of class and were given multiple group assignments during the term before they were given this case. Thus, groups had developed some group history prior to solving this case.

To alleviate the problem of unfair comparisons across treatment conditions and roles, each role was compared to the same role in the same treatment condition. Student grades were determined with respect to how well others with comparable roles and treatment conditions performed. To acquaint the subjects with the GDSS, a training session was held and a sample problem was solved. The formal experiment began after it was determined that the subjects fully understood the problem and the features of the GDSS. A description of the GDSS is provided in the Appendix II.

4.4. Measures

The outcome measures include decision quality, and the quality of information exchanged. The process measures include time taken to finish the process and converge to a group solution, frustration with the process, and the efficiency of the problem-solving process.

Decision quality is measured with respect to individual rewards achieved and the rewards relative to the efficient frontier. In multiple objective problems, the notion of optimality is replaced by an efficient frontier (also referred to as pareto optimality or nondominated

solution set). The notion of optimality needs to be qualified because a solution which optimizes one objective, in general, will not optimize other objectives (Cohon 1978; Stuer 1989). The efficient frontier consists of all solutions which cannot be dominated by another solution. That is, one cannot find a solution which improves at least one objective without degrading one or more of the other objectives.

We found the theoretical efficient frontier for the objectives of leader and members by formulating a two objective problem: One for the members, another for the leader. The problem was then solved iteratively using the weighting method of multiple objectives (Cohon 1978) In this method, one parametrically keeps changing the weights assigned to each objective to find the break-points in the efficient frontier. Once we found the efficient frontier, the points obtained from the experiment were compared against the efficient frontier (see figure 2). We represented the leader objective on the vertical axis and that of the members on the horizontal axis. The deviation from the efficient frontier was found by measuring the vertical and horizontal distances between the coordinates of each point representing a group solution within the experiment to the closest break-point (feasible solution) on the efficient frontier. This provides a measure of leader and member performance with respect to the best solution outcome each could achieve without hurting the other parties' outcome. For example, in figure 2, if one were to consider point c, if the leader could

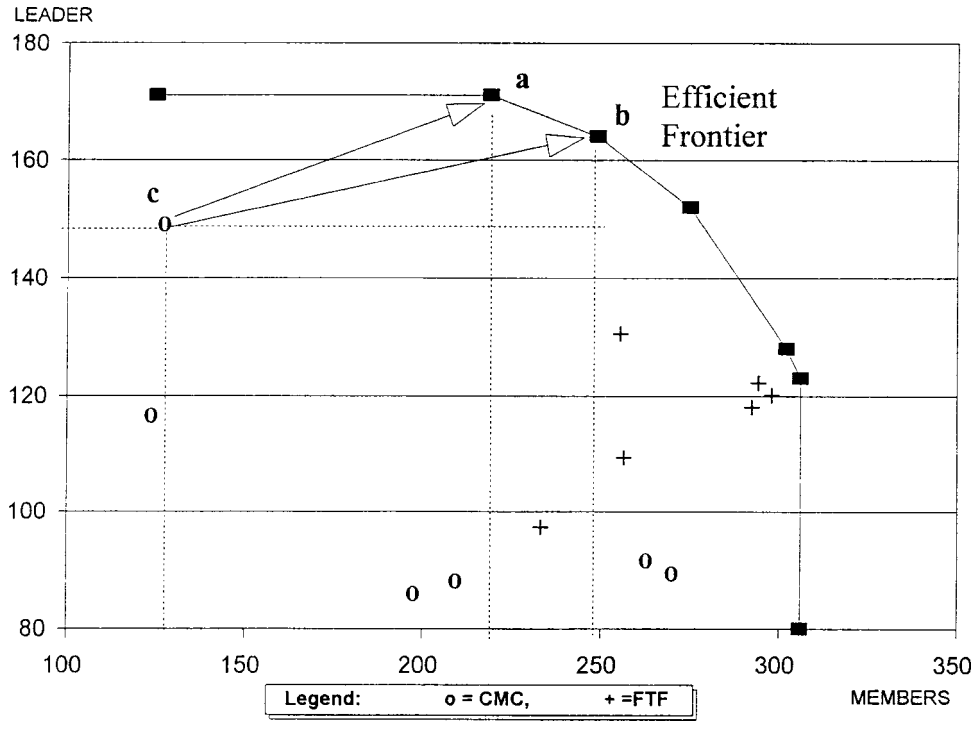

Figure 2. The theoretical efficient frontier and experimental results.

obtain adequate information and move to point a on the efficient frontier, he/she could increase his/her payoff by 20 units from 151 to 171, while at the same time the member payoffs would have increased from 130 to 219 an increase of 89 units. Similarly from the member's perspective if they could convince the leader to move to point b on the efficient frontier, their payoff would increase from 130 to 249, while at the same time the leader's payoff would increase from 151 to 164. Thus, in either case, moving from an interior point to the efficient frontier provides an improvement in both leader's and member's payoff.

5. Results

The research questions that result in the set of hypotheses proposed in this paper use individual-level data as the units of analysis instead of the group-level data (Hoyle and Crawford 1994). Hoyle and Crawford suggest that it may be more insightful to view the data from the individual level instead of the group level of analysis (Hoyle and Crawford 1994). They argue that many new research questions are suggested and the old questions are better understood by viewing the data from the individual level. Investigating individual-level variables, we can evaluate the contribution of individual group members to the functioning of the group as a whole. Table 1 depicts average member reward and the average deviation of the reward from the efficient frontier. The reward and deviation from the efficient frontier are used to measure performance. The results indicate that member reward is higher in FTF groups than in CMC groups ($p < .0005$[5]). The deviation of member rewards (horizontal) from the efficient frontier (see figure 2) is larger for CMC groups than for FTF groups ($.0005 < p < .001$). Based on these two measures of performance, we conclude that hypothesis HI, i.e that member performance of FTF groups is better than that of CMC groups, is strongly supported.

Table 2 depicts the leader's reward and deviation from the efficient frontier. Leader reward is higher for FTF groups than for CMC groups, however, this difference is not statistically significant ($p > .1$). As one can see from Table 2, the deviation from the efficient frontier for the CMC groups is larger than that for the FTF groups (See figure 2). This difference is statistically significant ($.01 < p < .025$). Based on these two measures of leader performance, hypothesis H2, that leader performance is better for FTF than for CMC groups, is not supported. The leader reward is not affected substantially by the communication channel, however, his/her reward is significantly closer to the efficient frontier when the communication channel is FTF than when it is CMC.

To operationalize a measure of information exchange truthfulness, we counted the number of times that members sent to the leader costs that were equal to what they actually incurred

Table 1. Member reward and deviation from efficient frontier

	Reward			Deviation		
Treatment	Average	Std. dev.	n	Average	Std. dev.	n
FTF	94.76	17.80	18	29.24	23.75	6
CMC	66.89	26.77	18	100.35	51.87	6

Table 2. Leader reward deviation from efficient frontier

Treatment	Reward Average	Std. dev.	n	Deviation Average	Std. dev.	n[6]
FTF	116.93	12.01	6	28.20	23.49	6
CMC	104.48	25.51	6	61.08	21.08	6

for each of the twenty orders. Because there are three managers per group and there are twenty orders, the sample size for this measure was 360 for each group.

Table 3 depicts the average number of deviations between the actual costs incurred at the departments and those reported to the leader for FTF and CMC groups. Each member exchanges the costs of twenty orders with the leader and hence the upper bound on the number of untruthfulness counts is sixty. Hence, the results depicted in Table 3 show that CMC groups reported an average of untruthful costs of 28.83 times and FTF groups 17.00 times.

Table 3 shows that members in FTF groups reveal their local cost information to the leader more truthfully than they do in the CMC groups, and hypothesis H3, that members in the FTF group will tend to reveal their departmental information to the leader more truthfully than the CMC groups, is supported ($p < .0005$).

To calculate the difference between the leader's expected performance and actual performance, we first calculate the leader's expected reward. The leader's expected reward is the reward he/she calculates based on the cost data that he/she receives from the members. The actual reward is the reward he/she receives based on the cost data that the members actually incur. If the cost data that the members incur and those that they report to the leader are equal, then the leader will receive a reward that is equal to what he/she expects. Using the costs that the members adopt and the costs that the members report to the leader, we calculated the actual and expected leader reward. Then we found the absolute value of the difference between them groups that belong to the same treatment condition.

Leader reward depends on the costs incurred at the three departments for the order are selected. Leader reward is equal to his (her) expected reward if he (she) receives accurate truthful cost information from the three managers. Figures 3a and 3b provide a graphical representation[8] of the leaders expected rewards ("Perceived" on the legend) relative to their rewards ("Actual" on the legend) for CMC and FTF groups respectively. The expected rewards or Perceived rewards are computed based on the cost information that is provided by the managers to the leader, while the actual reward is based on the actual costs that would be incurred in the departments. The experimental results on the difference of actual leader rev and his (her) expected reward is depicted in Table 4.

Table 3. Absolute distance from truthful information

Treatment cond.	Distance Average	Std. dev.	n[7]
FTF	17.00	15.74	360
CMC	28.83	20.74	360

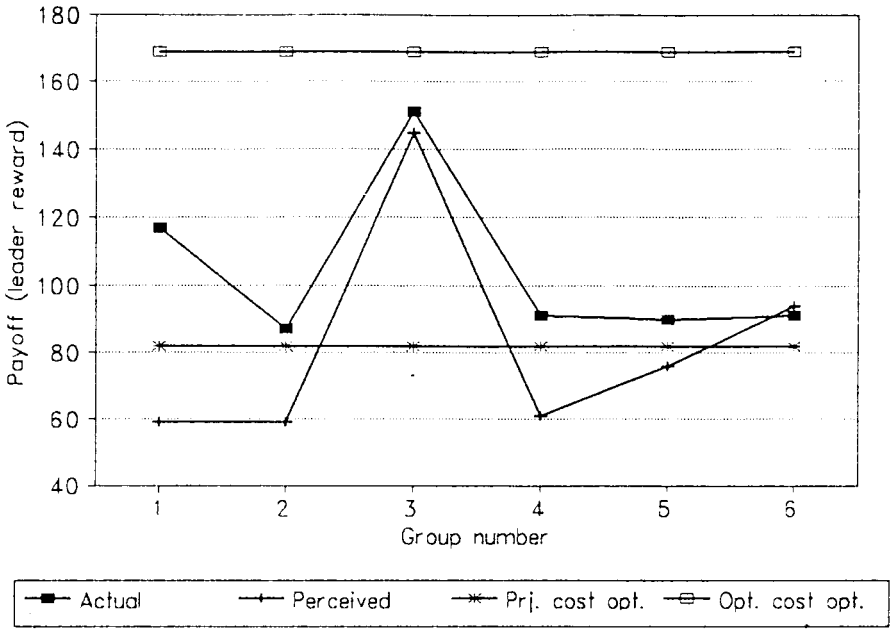

Figure 3a. Actual versus expected (perceived) leader reward for CMC groups.

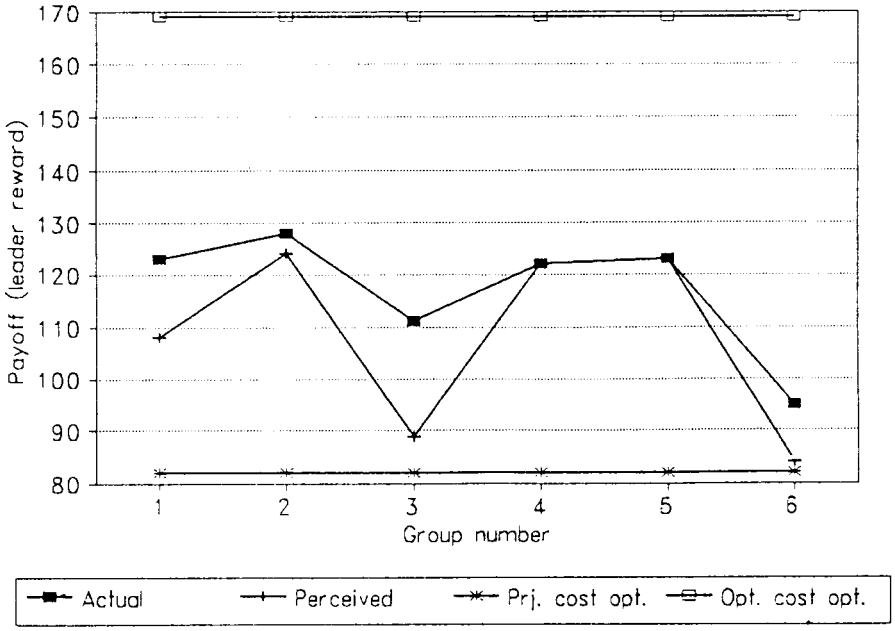

Figure 3b. Actual versus expected (perceived) leader reward for FTF groups.

On figures 3a and 3b, the upper horizontal lines correspond to the theoretical upper bounds on leader reward. The theoretical upper bound is calculated by using costs associated with the optimal effort levels for all orders in the leader's model and solving it to find the set of orders that maximize leader's reward ("Opt. cost opt." on the legend). It should be noted that if the set of orders were picked that optimized the leader's reward it could lead to extremely detrimental rewards for some of the managers. The lower horizontal lines correspond to the situation that the leader selects the best set of orders based on a model that uses projected costs ("Pd. cost opt." on legend). Although leaders in FTF groups have a better estimate of their actual rewards as illustrated in figures 3a and 3b, at our conservative alpha level of .05, this is not supported ($.05 < p < .1$). Hence, hypothesis H4, the difference between the leaders expected (perceived) and actual performance will be larger in CMC groups than in the FTF groups, is not supported.

The leader is aware of the projected costs at the departments, and hence, the lower horizontal line can be viewed to be the leader's reservation performance (since he/she knows that he/she can get at least this reward). We would expect that any choices he/she makes would result in a reward that is between the optimal and the reservation performance. In the FTF case this is indeed true. However, in the CMC case, as shown in figure 3a, some of the leaders will have an expected (perceived) payoffs that is lower than the reservation payoff. This may indicate that leaders in the CMC groups are unable to obtain accurate information from the members and, hence, may make irrational decisions.

The standard deviation of member rewards within a group was used as a measure of variability between member rewards. Table 5 provides the results on the variability[9] of member rewards for FTF and CMC groups. The average variability (spread) between member rewards is not smaller in FTF groups than in CMC groups. Hence hypothesis HS that the variance among member performance will be smaller for FTF groups than for CMC groups is not supported ($p > 0.1$). This indicates that leaders in both FTF and CMC groups are equally concerned with adopting a set of orders where the member rewards are comparable. Communication media does not seem to be an important variable affecting equality of member rewards (i.e. leader fairness). This may be due to the fact that groups have some group history

Table 4. Difference of actual and perceived leader reward

Treatment	Difference Average	Std. dev.	n
FTF	8.67	8.12	6
CMC	22.50	19.14	6

Table 5. Variability of member rewards

Average	Std. dev.	n
12.56	11.57	6
13.50	13.10	6

and, furthermore, need to maintain their relationships for future projects. Hence, group history and expectation of future cooperation seems to mitigate some of the negative impacts, namely leader fairness, of de-individuation and social presence on mixed-motive tasks that result from computer mediated communication.

We next analyze the effect of communication media on frustration with the process. The results of the post experimental questionnaire on the self reported Likert scale for frustration with the process in Table 6.

The difference in member frustration with the process is statistically significant between FTF and CMC groups. Members in CMC groups were more frustrated with the process ($p <$ .0005), leading us to accept hypothesis H6a that member frustration with the process will be lower in FTF groups than in CMC groups. For the leader, the level of frustration is higher for CMC groups than for FTF groups, hence hypothesis H6b that leader frustration with the process will be higher for CMC groups is accepted ($.01 < p < .025$). Table 7 reports the average time taken to converge to a solution. This is a surrogate measure of efficiency of problem-solving.

There was no difference in time ($p > .1$), thus hypothesis H7 that the time to converge to a solution will be longer for CMC groups than for FTF groups was not supported. Although it has previously been proposed that the restrictive communication media may increase the communication time and hence the decision time, our results show that the FTF groups take almost as long to converge for mixed-motive tasks. Several explanations are possible. First, the FTF groups are more likely to be less task-focused than CMC groups (Nunamaker et al. 1991) leading to longer time duration to converge to a solution. Second, it may be easier for a leader in CMC groups to impose a solution and terminate the negotiation process faster than for a leader in FTF groups. These factors seem to neutralize the possible inefficiencies that we expected to result from the restricted CMC channel.

Table 6. Frustration with the process

Member Treatment	Leader Average	Std. dev.	n	Average	Std. dev.	n
FTF	4.00	1.2	18	3.67	1.49	6
CMC	6.22	1.18	18	5.50	1.12	6

Table 7. Time to converge

Treatment cond.	Time (m) Average	Std. dev.	n
FTF	1006.7	32.74	6
CMC	114.67	24.50	6

6. Discussion

Table 8 summarizes the experimental results. It presents each hypothesis and shows if it was statistically supported or not supported at the conservative .05 alpha level.

It was interesting to find that although the tool provided an efficient method to communicate problem specific information, the ability to communicate in a FTF manner still resulted in better overall performance of the groups. This was especially true for the group members. The leaders in the FTF groups performed better than the leaders in the CMC groups on one of the measures of performance (efficient frontier), but not the other (reward). Hence, the authority given to the leader seems to mitigate, to some extent, the effect of communication media.

It is interesting to note that since the group needs to work together in the future, behavior in the CMC mode is dependent on whether the individual can be identified with an action or not. The leader, who is identified with the decision tends to be fair as evidenced by the minimal variability between the member rewards. However, members in the CMC groups tend to exploit private information more than the FTF groups. This is evidenced by the larger proportion of inaccurate costs being submitted to the leader in CMC groups. Untruthful information exchange is not a desirable behavior and the fact that it is promoted in CMC groups, using a communication channel that is characterized by such words as unsociable, insensitive, cold, and impersonal, lends support to the observation made by (Siegel et al. 1986) that CMC groups engage in antisocial behavior to a larger extent than FTF groups.

The results of this study also lend support to the McGrath and Hollingshead (1993) hypothesis that for mixed-motive tasks the computer-mediated communication mode is a poor fit. Although prior studies indicate that the CMC groups tended to take longer times, in our study the CMC groups took the same time to reach solutions as did the FTF groups. This could be a result of several factors. Providing an efficient approach to communicate task specific information may mitigate some of the inefficiencies of the CMC mode of communication. Additionally, it is possible that in the FTF group, group members may tend to spend more time trying to ensure an equitable solution while in the CMC group the leader may decide to terminate the process once he/she is more or less satisfied with the results.

Table 8. Summary of hypotheses and their significance

HI: Member performance		
reward	FTF > CMC	s
deviation from E.F.	FTF < CMC	s
H2: Leader performance		
reward	FTF > CMC	ns
deviation from E.F.	FTF < CMC	s
H3: More truthful reporting	FTF > CMC	s
H4: Leader expected versus actual reward	FTF < CMC	ns
H5: Variance among member reward	FTF < CMC	ns
H6a: Member frustration with the process	FTF < CMC	s
H6b: Leader frustration with the process	FTF < CMC	ns
H7: Time to converge to a solution	FTF < CMC	ns

s – hypothesis supported at. 05 level; ns – hypothesis not supported at .05 level.

7. Limitations

The first potential limitation arises from the use of student subjects. The use of student subjects as surrogates for actual decision makers has been justified (McGrath 1984) when members are familiar with the task and have significant stakes in the outcomes. The students in this study had significant stakes in the outcomes and were very familiar with the task as it was introduced in conjunction with related topics in class.

The number of groups per cell is six. Larger cell sizes would provide stronger statistical results. The use of a sample size of six, is however, not far from the tradition for controlled studies on groups. Chidambaram and Jones (1993) have sample sizes of six. In addition, many of the hypotheses that are proposed in this paper treat an individual group member to be the unit of analysis and because we have three members per group, the sample size for these hypotheses were essentially eighteen.

The task used for this study is an example of a mixed-motive task. One should be cautious about generalizing the results of this study beyond mixed-motive tasks or even to other mixed-motive tasks with different characteristics.

8. Future directions

Although distributed group decision-making is on the increase, little is known about the impact of many key group and organizational factors and how they influence group decision processes and outcomes in this environment. The range of potential factors to be studied, broadly defined, spans those relating to individual characteristics, GDSS characteristics, and organizational characteristics in distributed decision settings. For example, the influence of group composition and incentive mechanisms in CMC environments would be one dimension the current work can be extended. Furthermore, the interaction between these factors and the communication mechanism on negotiation behavior [i.e. distributive or integrative[10] (Ruble and Thomas 1976)] needs to be explored.

Notes

1. For a study of electronic mail and its impact on reducing social context cues the reader is referred to Sproull and Kiesler (1986).
2. Based on the results of a pilot study with nine groups, the groups without a GDSS were overwhelmed by the complexity of the task and their solutions were far worse than those that had the GDSS. The frustration was very high and they had a hard time finding reasonable answers.
3. In the experiment the members were confined to a cost specification interval so that if they provided untruthful information, it was not too unreasonable and hence unbelievable.
4. One of the authors was always present during all experiments to answer any questions so that the results were not confounded by one treatment condition not knowing how to use the system or how to interpret the numbers.
5. We use an alpha level of .05 to test each hypothesis proposed in this paper.
6. There is one leader per group and since there are six groups per cell, the sample size n is equal to 6. When we consider individuals within the group, the sample size is 18 because there are three members

per group.
7. Three members in each of the six groups each reporting costs for 20 orders.
8. Note that the points are connected to show the pattern. It does not imply that there is some type of interaction between the points that are connected.
9. The variability among member rewards within each group is represented by the standard deviation of the three managers' rewards. The average variability is reported in Table 4.
10. Negotiators using a distributive approach view negotiation as a 'win-lose' situation, conceal information and employ pressure tactics to elicit unilateral concessions. With the integrative approach, the negotiators view the process as a 'win-win' situation, exchange truthful information, and express support for a mutually acceptable outcome.

Appendix I: Task Model

Each member is faced with a problem that can be modeled as follows:

$$Max \quad \sum_{i \in S} \sum_{i \in E} [(PC_{id} - ADC_{ijd})\ 60\% - UDEC_{ijd}]\ X_{ij}$$

$$S.t.$$

$$\sum_{i \in S} Q_{ik}\ Y_i < Capacity_k \qquad \forall\ k \in K$$

$$\sum_{j \in E} X_{if} = Y_i \qquad \forall\ i \in S$$

where,

$$X_{if} = \begin{cases} 1 \text{ if order } i \text{ taken at effort level } j \\ 0 \text{ otherwise} \end{cases}$$

$$Y_i = \begin{cases} 1 \text{ if order } i \text{ taken} \\ 0 \text{ otherwise} \end{cases}$$

Q_{ik} = *Quantity of product* $k \in K$ *required in order* $i \in S$
$i \in S$: S = *Set of Orders* = 1,2,..,20
$k \in K$: K *Set of Products* = 1,2,3,4
$d \in D$: D = *Set of Departments = Mkt, Prd, Purch*
$j \in E$: E = *Set of effort level choices* = 1,2,3,4

The second sub-problem can be modeled as follows:

$$Max \quad \sum_{i \in S} \sum_{j \in E} [(PC_{id} - ADC^*_{di})\ 60\% - UDEC^*_{id}]\ Y_i$$

$$S.t.$$

$$\sum_{i \in S} Q_{ik}\ Y_i < Capacity_k \qquad \forall\ k \in K$$

where,

ADC_{id}^{*} = *ADC for optimal effort level* $j \in E$
$UDEC_{id}$ = *UDEC for optimal effort level* $j \in E$

The leader's problem is captured by the following model:

$$Max \quad \sum_{i \in S} [9\% \, (Rev_i - \sum_{d \in D} ADC_{id})] \, Y_i$$

S.t.

$$\sum_{i \in S} Q_{ik} \, Y_i < Capacity_k \qquad \forall \, k \in K$$

where,

Rev_i = *Revenue generated by filling order* $i \in S$

Appendix II: The GDSS

A GDSS was designed to support the problem solving and communication needs of the groups. The GDSS ran in a PC windows environment with a LAN supporting Novell Netware. Both FTF and CMC groups had access to this GDSS. The FTF groups were seated at four tables facing one another to form a square table, whereas the CMC group members were seated separately, each isolated from others, so that they could not see or talk to one another. The FTF groups could engage in verbal communication but the CMC groups had to communicate through the electronic communication channel to exchange messages (i.e. like a real-time e-mail system).

The GDSS features include: modeling and optimization capability, information exchange facilities, what-if capability, and a group memory capability. We classify the GDSS as a Level 2 GDSS as defined by DeSanctis and Gallupe (1987) because of its modeling capability. The GDSS provides process support (i.e. information exchange via pre-defined templates) , task structure (i.e. modeling and what-if capability), and task support (i.e. optimization capability) corresponding to the framework proposed by Nunamaker et al. (1991).

The system consists of three main screens: GDSS Menu, Outgoing Messages, and Public Message Board. The information exchange facility allows users to send text messages as well as task-specific templates of information. The screen for textual message exchange has two major windows. In one window, the outgoing message board, the user may type messages for others. In the other window, public message board, the user may observe all messages that have been sent to him (her) by everyone else. The sender of the message can select from a menu the group members who are to receive his (her) messages. Each user can scroll to previous messages sent to him (her) on the Public message board.

The task-specific templates provide a means to exchange information pertaining to the task. Examples of such templates include those that allow members to transmit their departmental cost information to others, or to propose solutions to others. These templates facilitate task specific information exchange and automatically update the local database of message recipients.

The modeling capability selects a knapsack model from the model-base component of the GDSS and uses the information at the individual's database as parameters to formulate problem instances and solve them optimality for each decision-maker. Because each member needs to specify the effort he (she) will exert, a preliminary window will pop up to ask each member to assign a specific effort level (from least = l to max = 4) to each order. The GDSS accesses the costs (ADC and UDEC) associated with these effort levels from the users database and formulates an instance of the knapsack problem. Once the instance is formulated, the GDSS calls an optimization module to optimize the model instance and presents the solution along with the corresponding reward to the user. The leader's database may be updated if members send him (her) a template with their ADCS. The leader problem instance is formulated

by using information in his (her) database. This information has projected costs as default but the members may update these corresponding with their departmental costs.

The solution evaluation capability allows one to perform what-if type analysis. This feature allows each person to examine, from his (her) perspective, the solutions proposed by others as well as incremental changes to solutions.

Finally, a group memory capability keeps a history of all proposed solutions by the various group members. This feature aids in the negotiation process by providing a participant information about the preferences of other individuals and how it is changing over time.

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