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Sampling and pooling of decision-relevant information: Comparing the efficiency of face-to-face and GSS supported groups

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Abstract

Past research has suggested that decision-making groups, when communicating face-to-face (FtF), suffered from information sharing biases that affected the quality of the final decision: they tended to discuss previously-shared information before they started to discuss information not known to all, and discussed more of previously-shared than unshared information. In our study we examined these effects in groups that interacted FtF or using a group support system (GSS). Four-member groups discussed a requirements elicitation task in which some requirements were known to all members before starting their discussion, while other requirements were known only to two members of the group. Both GSS and FtF groups exchanged a large percentage of the shared requirements. However, the GSS groups were more effective in communicating unshared requirements. On average, FtF groups discussed shared requirements sooner and unshared requirements later than did GSS groups. Our study also compared empirical results with predictions from an information-sampling model of group discussion in order to assess the effectiveness of the model in computer-mediated group communication.

Keywords: Information sampling; Information pooling; Shared information; Group communication; Group support systems; GSS

1. Introduction

One of the important factors that gives group decision makers an advantage over individual decision makers is the amount and diversity of relevant information held by the group due to its members' differing roles, responsibilities, training, and experience. The group therefore is more likely to make informed and high quality decisions. However, in order to utilize their informational resources, they must discuss and exchange them. Some researchers have stated that communication quality is the most important factor influencing the group's success or failure [13].

Task-related information known by all members of a work group is termed *shared* information, while that held only by one or few group members is considered *unshared* [29]. Both types of information play important roles in group decision making: e.g., shared or redundant knowledge may help establish a common understanding and help consensus building [3]. From an information resource perspective, however, the differential advantage of groups over individual decision makers lies in the unshared information; this occurs, for example, in a design team of experts from different fields or an advisory committee of representatives from different organizational units.

Thus *shared information* is task-related information that every member of the group holds while *unshared information* is task-related information held by one or more, but not all, group members. *Information sampling*

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is the process by which group members introduce task-related information into a discussion by recalling and mentioning it. The collection of task-relevant information known by every member is termed the *pool* and thus *information pooling* is the process of creating and enlarging the pool of shared information through group discussion.

Past research suggested that the pooling suffered from two biases [15]. First, groups tended to discuss their shared information more than the unshared knowledge. Unshared information was sometimes not discussed at all, hence depriving groups of potentially useful or critical knowledge. Second, unshared information was often introduced late in the discussion. This could mean that some unshared but important information had little effect on the group decision.

A statistical explanation of these biases was suggested by Larson [18], who argued that when only some members hold unshared information and the number of them is small, the probability of surfacing that information early is also relatively small. Based on this, he proposed a dynamic information-sampling model of group discussion (DISM-GD) and developed a computer program that implemented it; subsequent research on FtF discussions has generally supported its validity.

We examined these information sharing biases in the context of two environments: FtF and GSS-supported discussion. We also compared empirical results with predictions generated using the DISM-GD program to see whether the model also worked for computer-mediated group communication.

2. Theoretical foundations, prior research, and hypotheses

Some authors see discussions in groups as collective information processing (CIP) that affect the ways in which information, ideas, or cognitive processes are shared and how this affects outcomes [12]. The group, as a collective unit, must share, synthesize, evaluate, and use the information. Forming an information base or a collective pool is a requisite for effective CIP and problem solving [14,22]. Information sampling and pooling play a central role in the process [23].

2.1. Group support systems and information sampling and pooling

In order for groups to build a common pool of knowledge, they must share their individual memories. Individuals engage in three cognitive processes to manage their informational resources [6]: information recall, information exchange, and information processing (evaluating and storing it in memory). For an effective group communication, an important objective should therefore be to facilitate and support these cognitive processes. Groups need to ensure that their knowledge is shared, evaluated, and incorporated. The social cognitive perspective of CIP views a group as an entity with a single collective cognition [11]. There are, however, obstacles to constructing collective cognition in diverse, cross-functional, or distributed groups: structural diversity can lead to communication and information sharing inefficiencies. Teams face challenges because of reduced opportunity for informal discussion and a need to understand different ‘‘thought worlds’’ [16]. Also, though socio-technical systems help increase productivity of distributed work groups such as those engaged in software development, they can impede the flow of information among team members [32,33].

The literature has shown evidence that groups were inefficient in exchanging initially shared and unshared information [20]. In one study of FtF groups [27], participants pooled only 46% of their shared and only 18% of their unshared information. In another study that used a ‘‘hidden profile’’ task [26], failure to share *unshared* information lead to incorrect, suboptimal, and disastrous decisions. In a hidden profile, a superior decision alternative exists but is hidden from one or more team members.

GSS are among the most studied software systems for collective decision-making [1]. These systems are sometimes categorized as level 1 or 2 [7,8]: Tools that enable and enhance group communication are at level 1, whereas those designed to aid decision making are at level 2. Level 1 tools can affect sampling and pooling of information in several ways. First, unlike FtF discussions, the communication occurs in parallel, allowing members to contribute without waiting their turn or being interrupted. Parallel communication gives participants the ability to alternate between contributing and reading others' ideas. However, engaging in parallel cognitive activities can impede the processes of information recall, evaluation and exchange [2]. Second, an automated, digital memory in a GSS can store all the contributed information for browsing during or after the meeting. This serves important group-level attentional and short-term memory functions [17]. Third, social and behavioral factors may lead to ‘‘production blocking’’ and impede information recall and exchange [24]. By limiting social context cues, GSS can remove barriers to communication, promote equality of participation, and enhance information exchange [5,25].

These ideas lead to the following hypotheses.

H1a. GSS groups will pool more information, overall, than FtF groups.

H1b. GSS groups will pool a higher percentage of shared information than FtF groups.

H1c. GSS groups will pool a higher percentage of unshared information than FtF groups.

The temporal pattern of sampling in FtF groups is apparently biased in favor of shared information. That is, items of information that are shared prior to a discussion have a greater likelihood of being introduced into discussion sooner than comparable unshared ones. Thus we expected FtF groups to experience sampling disparities. Although there is little such GSS sampling research, the cognitive and behavioral influences of GSS communication lead us to test the following hypotheses.

H2a. Shared information, on average, will be introduced earlier in FtF groups than in GSS groups.

H2b. Unshared information, on average, will be introduced later in FtF groups than in GSS groups.

2.2. Dynamic information sampling—a statistical perspective

In one of the early attempts to explain the information pooling disparities in group discussion, Stasser and Titus [28] proposed a collective information-sampling (CIS) model:

$$p(D) = 1 - [1 - p(M)]^n \quad (1)$$

The probability that the group will discuss an item, $p(D)$, is a function of the number of members who hold that item of information, n, and the likelihood that any one of these members will mention it, $p(M)$. An implication of this is that as the number of members who share an item increases, the likelihood of that item's being discussed increases. Although subsequent research provided general support for this model, it rested on several assumptions that often do not hold in real group settings: it assumes that shared and unshared items are equally important and all group members have equal rates of recall and communication ability (i.e., none are more alert or talkative).

Larson's DISM-GD extended the CIS model to account for sampling and pooling. The model suggests these biases can be explained as purely statistical consequences of the distribution of decision-relevant information among group members prior to discussion. The discussion can be viewed as a sampling process that allows members to exchange information. If n members hold k_s items of shared information, there are $[nk_s]$ opportunities to bring the item into discussion but only $[1k_u]$ opportunities to sample an item of unshared information. Therefore, the probability of sampling an item of shared information is

$$p(\text{shared}) = \frac{nk_s}{nk_s + k_u} \quad (2)$$

Similarly, the probability of sampling an item of unshared information is

$$p(\text{unshared}) = \frac{k_u}{nk_s + k_u} \quad (3)$$

Initially, the probability of sampling shared items will be higher than that of unshared items. As the discussion continues, members recall and mention items and the probabilities start to change. The rate of change at any time depends on the distribution (or proportion) of shared and unshared items. Over time, with the decrease in this proportion, the sampling probabilities turn in favor of unshared items being discussed more frequently. This model does not make any assumptions about individual members' rates of recall and contribution; it accepts different values of these parameters in order to allow generation of predictions for different conditions.

The two information-sampling models have received empirical support in FtF group communications when equal-status members have comparable information loads, shared and unshared items are similar in relevance, and there are no cues to help members distinguish shared from unshared items [30]. The empirical work, however, did not account for various psychological and social variables that characterize ''real-life'' decision-making groups. These models are only baseline models that can help in understanding the effects of information distribution on dissemination of information [31]. For example, one could examine the impact of extraneous variables as deviations from model predictions.

Since the DISM-GD model generally ignores all social and behavioral influences, we expected GSS discussions to deviate little from the model's predictions. FtF discussions, on the other hand, are characterized by social context cues and interplay of complex behavioral and psychological variables. We therefore anticipated FtF outcome to differ significantly from the estimates. Hence, we made the hypotheses:

H3a. For pooling and sampling of shared and unshared information, GSS discussions will not deviate significantly from the model predictions.

H3b. For pooling and sampling of shared and unshared information, FtF discussions will deviate significantly from the model predictions.

3. Methodology

3.1. Research design

Specifically, our study was intended to consider the exchange of information either completely shared or uniquely held by group members prior to discussion. A 2×2 mixed-factorial experimental design was therefore used; in it information distribution was a within-groups factor and distribution of shared and unshared items of information was uniform across all groups in all conditions. Dependent measures were generated through FtF and GSS group discussions, and also using the DISM-GD software.

3.2. Dependent measures

Dependent measures of pooling and sampling were the *percentage of information items pooled* during discussion and *serial position* of shared and unshared items when discussed, respectively. The proportions were calculated as the number of shared and, separately, unshared items mentioned at least once, divided by their counts in the case (six and four, respectively). Using procedures from [19], item serial positions (e.g., first, second, third) were found by noting when an item was first brought into discussion. Mean serial position of both shared and unshared items in each treatment was calculated. Means for the entire set of FtF and GSS groups were then derived.

3.3. Model parameters

In order to generate predictions using DISM-GD, it was necessary to estimate three parameters. First, estimates of $p(R)$ obtained in past studies ranged from 0.71 to 0.81. We used the average, 0.76. Second, $Cp(R)$ was set equal to $p(R)$. This meant that members' memories were independent of one another—which seems to be a reasonable assumption. Third, *cRatio* has a maximum possible value of 1.0 (when all members contribute equally). Empirically obtained estimates of equal-status FtF groups have ranged from 0.70 to 0.84. We used the average, 0.77, for FtF groups. There was, however, no a priori estimate for GSS groups but evidence in the GSS literature suggests that GSS-based communicative environments promote equality of participation by allowing parallel communication and reducing production blocking. We therefore assumed that GSS group members would participate equally and set *cRatio* for GSS groups at 1.0.

3.4. Participants

Participants were undergraduate business students enrolled in sections of a systems analysis and design course at an accredited US university. As part of a course, they had been instructed in material on system requirements elicitation using interviewing techniques. From the 197 students, 48 four-person groups were randomly formed (two groups of two and three students were excluded from analysis). Two members in each group were assigned the role of systems analysts while the others assumed the role of clients. Students received credit for their participation in the study.

3.5. Task

The requirements elicitation task involved the design of an information system [9]. The case (described in Appendix A.1) was for a fictitious fast food company that operates many stores throughout the US and needs a new point of sale system. The case narrative contained ten information items considered essential (see Appendix A.2). Six of these items were shared among all four members and two items each were uniquely held by the two representing clients. The shared and unshared items were interspersed in the case narrative. The distribution of unique items was consistent with that of hidden profile tasks; the four uniquely held items had to be revealed and discussed or the set of requirements and consequent design would have been deficient.

The requirements elicitation task was selected because the students knew the methods and could relate to it. The task was therefore expected to enhance their participation and interest. Also requirements elicitation and alternatives generation tasks seek to maximize retrieval and exchange of information [21] with information that is more or less neutral and thus more likely to be shared than that perceived as expertise or specialized [4].

3.6. Procedure

All participants were given a hands-on introduction to an electronic brainstorming tool, *GroupSystems*. Groups were then formed and each held an introductory

Table 1a
Mean (standard deviation) of dependent variables—empirical data

Variable	FtF			GSS		
	Shared	Unshared	Total	Shared	Unshared	Total
Percent of information pooled	84.0 (9.2)	48.9 (15.6)	66.5 (21.8)	83.3 (12.0)	76.0 (17.3)	79.7 (15.2)
Average serial position	3.4 (0.6)	5.8 (1.6)	4.6 (1.7)	4.1 (0.9)	5.1 (1.0)	4.6 (1.1)

meeting in an FtF setting: for 15–20 min, they discussed user requirements for a university system that processes student enrolment and generates grades reports. They were then randomly assigned to one of the two treatments: GSS or FtF.

Just before starting a group discussion, the four participants were randomly handed written case descriptions. Two were subtitled: ‘‘You are a systems analyst’’ and contained only six shared items of information. Each of the other two descriptions was subtitled: ‘‘You are a client’’ and contained the six shared plus two unique items. Participants were given instructions asking them to elicit and discuss as many user requirements as possible.

GroupSystems discussants signed-on using their names and the group members sat in close proximity in the computer lab but were instructed not to engage in verbal communication. Discussions of FtF groups were audiotaped. Each member in an FtF group began by saying aloud her or his name and role. Groups were told to deliberate for about 45 min; the actual discussions took from 35 to 50 min.

Computer-generated records of *GroupSystems* discussions were printed out for coding. Audiotapes of FtF discussions were transcribed and coded. The 10 items of information were assigned abbreviated codes. First mention of an information item was highlighted and its code written in the margin of the transcript. Repetitions were not coded. Coded transcripts were then used to determine which of the ten information items were discussed and in what order.

4. Data analysis and results

Means and standard deviations of the dependent variables and ANOVA test results are shown in Table 1. Since perceived importance of an information item could potentially influence whether it was discussed sooner or later than others or was not discussed at all, a check for the inclusion and distribution of information items was conducted. A question in the post-meeting questionnaire asked participants about the relative importance of information items on a five-point scale; 79.7% judged all items either equally or approximately equally important for the system design decision, ($\chi^2 = 67.7$, $p < 0.01$).

Normality of the dependent variables was confirmed by using Shapiro–Wilk statistics. Levene’s test was also used to determine the homogeneity of variances. In cases where this assumption did not hold, we used alternate statistics that do not assume equal variances.

4.1. Information pooling

The analysis revealed a significant main effect for the mode of communication: $F(1, 92) = 21.7$, $p < 0.01$, partial $\eta^2 = 0.19$. This meant that overall, GSS groups pooled more information than FtF groups; H1a was thus confirmed. The ANOVA tests also revealed a significant interaction between communication mode and information distribution. Follow-up simple main effects analyses were conducted to examine the interactions. Both the GSS and FtF groups exchanged an approximately equal percentage of their prediscussion shared information and there was no significant difference between the two: $F(1, 92) = 0.03$, $p = 0.86$. Thus H1b was not supported. However, GSS groups pooled significantly larger percentage of unshared information than did the FtF groups, confirming H1c: $F(1, 92) = 45.7$, $p < 0.01$.

4.2. Information sampling

Analysis of variance of the dependent variable *average serial position of information items discussed*

Table 1b
ANOVA test results: GSS vs. FtF—empirical data

Dependent variables	Communication mode (CM) (GSS vs. FtF)	Information distribution (ID) (shared vs. unshared)	Interaction (CM × ID)
Percent of information pooled	$F = 21.7$, $p < 0.01$	$F = 55.9$, $p < 0.01$	$F = 24.0$, $p < 0.01$
Average serial position	$F = 0.1$, $p = 0.76$	$F = 60.5$, $p < 0.01$	$F = 10.6$, $p = 0.02$

Table 2a
Mean (standard deviation) of dependent variables—model estimates

Variable	FtF			GSS		
	Shared	Unshared	Total	Shared	Unshared	Total
Percent of information pooled	59.7 (1.7)	21.4 (1.7)	40.6 (19.4)	59.7 (1.7)	30.4 (1.7)	5.4 (1.1)
Average serial position	4.2 (0.7)	5.6 (0.7)	4.9 (0.7)	4.3 (0.2)	6.5 (0.7)	5.4 (1.1)

showed that the main effect for communication mode was not significant: $F(1, 92) = 0.10$, $p = 0.76$. Although we did not hypothesize this, the GSS and FtF groups exhibited no significant differences in this variable. The analysis showed a significant interaction effect: $F(1, 92) = 10.6$, $p = 0.02$.

In terms of serial position, FtF groups discussed shared items of information somewhat earlier in their discussion than the GSS groups. H2a thus received moderate support: $F(1,92) = 4.4$, $p = 0.04$. Also, as expected, FtF groups introduced items of unshared information into their discussions later than GSS groups: $F(1, 92) = 6.4$, $p = 0.01$. This confirmed H2b. Information-sampling results are shown in Fig. 1.

4.3. Empirical results versus predictions of the DISM-GD model

Table 2 contains means and standard deviations of the dependent variable values generated using the model; it also shows ANOVA test results for the empirical and model-generated means. An examination of the results indicates that the observed and predicted means are significantly different in all cases, except that for average serial position ($F(1, 92) = 2.3$, $p = 0.13$).

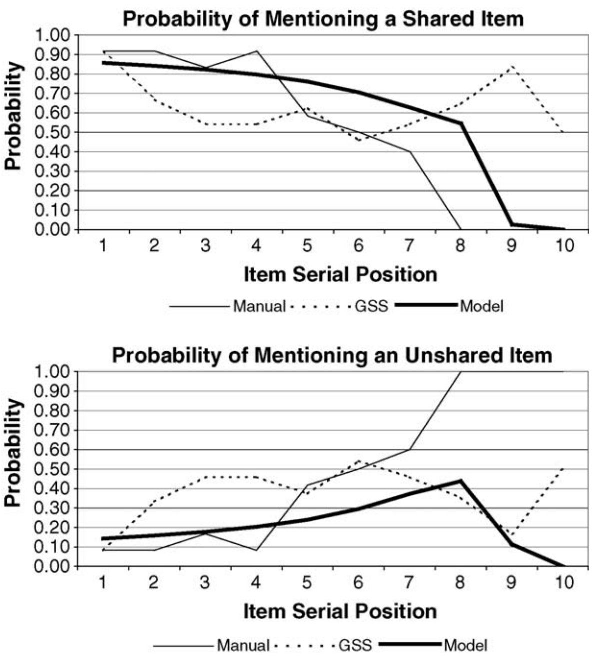

Fig. 1. Item serial positions of FtF and GSS groups and as predicted by the model.

For GSS groups, the model under-predicted the pooling of both shared and unshared information. The disparities were significant: $t(46) = 9.5$, $p < 0.001$ for shared and $t(46) = 12.9$, $p < 0.001$ for unshared items. As for information sampling, the model correctly predicted average serial position of shared information items but failed to predict that of unshared items. Overall, H3a received partial support—only one out of four components was confirmed.

In FtF discussions, predictions generated by the model were also far from correct. The model estimates of pooling were significantly lower than the observed values for both the shared and unshared items. Only the average serial position for unshared items was predicted correctly by the model, indicating no difference between the predicted and observed values. Observed serial positions of shared items were significantly lower than those predicted by the model. Thus H3b also received partial support—three out of four components were confirmed. In sum, although the model was not very successful in predicting the *magnitude*, it did predict correctly the *direction* of pooling and sampling of shared versus unshared information in both FtF and GSS groups.

5. Discussion and limitations

Face-to-face groups were inefficient in sharing overall information and were particularly deficient in recall and exchange of uniquely held information. They

Table 2b
ANOVA test results: empirical vs. model estimates—main effects

Dependent variables	Empirical FtF vs. model FtF	Empirical GSS vs. model GSS
Percent of information pooled	$F = 193.4$, $p < 0.001$	$F = 256.4$, $p < 0.001$
Average serial position	$F = 2.3$, $p = 0.13$	$F = 33.4$, $p < 0.01$

discussed about 2/3rd of the total and about 1/2 of the unshared information. These findings are consistent with prior research. GSS-supported groups, on the other hand, were significantly better than FtF groups at recall and exchange of the total and unshared information. Furthermore, they generally brought unshared information into discussions earlier than FtF groups. However, we did not examine communicational efficiency of the GSS per se. That is, this study does not demonstrate if the disparities can be reduced or avoided altogether by using a GSS.

Another limitation of the present research is that it was conducted with ad hoc groups, but many organizational work groups are long-standing with members having a history of working together. The dynamics of information sharing in such groups are inherently different from those of our study. First, members of intact groups are usually aware of each other's areas of expertise and possession of task-relevant information; this may promote (or inhibit) information sharing. Second, such groups often have one or more natural leaders who facilitate information sharing. Third, such groups are often characterized by competing interests, differing motives, and conflicting goals.

Regardless of the medium of group communication, our findings point to the need for better information management in task groups. For example, enhancing awareness about group members' activities and interests can improve group work coordination and quality of communication [10]. More specifically, since unshared information seems to have a disadvantage over shared information, it would be helpful to know which group members hold which pieces of task-relevant unshared information prior to a discussion. Appropriate intervention strategies can then be devised to facilitate or encourage sharing of that information.

One of our objectives was to examine efficacy of the DISM-GD model in groups using a GSS. In the study, the model consistently predicted the direction but not the magnitude of dependent variables. Disparities between the observed and predicted values were generally large and statistically significant. As for viability of the DISM-GD model for GSS-supported information exchange, our findings suggested that the model would need significant adjustment for it to serve as a baseline or reference.

6. Conclusion

Poorly communicated requirements causes many IS projects to fail. We examined information sampling and pooling, two concepts that are central to the quality of group communication, and conducted a study in which simulated teams of systems analysts and clients exchanged system requirements in either FtF or GSS supported meetings. We also compared empirical results with predictions of an information-sampling model of group discussion.

Although there was no significant difference between FtF and GSS groups in their exchange of shared information, use of a GSS did affect exchange of unshared information. GSS groups exchanged significantly more of their unshared information. GSS use also affected the temporal order of introducing items of shared vs. unshared information; FtF groups generally discussed shared requirements earlier and unshared requirements later than did GSS groups.

Comparison of empirical results with predictions from the DISM-GD model indicated that the model was not successful in predicting the magnitude of information sampling and pooling for both groups. It did, however, predict direction of the results consistently.

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Appendix A. The business case and items of information

A.1. The business case (unshared items are italics)

Master Burger Company is a fast-food franchise business with headquarters in Lemming, California. Currently it operates more than 270 stores in the United States and Europe, and *it is planning to expand to New Zealand and Australia*. The company's mission always has been to provide fresh food and exceptionally fast service, so *it maintains a very simple menu* of food items to avoid any spoiled or stale food. *The company also plans to provide drive-thru windows* at many of its restaurants. Gill Clark, the information services manager, wants you to design a point-of-sale cash register system to be used in each of Master Burger restaurant. The system will be used to take and fill customer orders. Ultimately, *the company will use the cash register system to perform additional tasks, such as tracking inventory.*

A.2. Items of information and their codes (in parentheses)

1	This is a franchise business (FR)
2	Company currently operates 270 stores (270)
3	Company plans to expand operations to New Zealand and Australia (NZ)[a]
4	One business objective is to serve fresh food (FF)
5	Another business objective is to provide exceptionally fast service (FS)
6	Company restaurants offer a simple menu (SM)[b]
7	Some restaurants will have drive thru windows (DT)[a]
8	Company's current stores are in the US and Europe (US)
9	Company needs a new point of sale system (POS)
10	The proposed system will also be used for inventory tracking in the future (INV)[b]

[a] Items uniquely held by one client.
[b] Items uniquely held by the second client.

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