The Effects of Interaction Frequency on the Productivity and Satisfaction of Automated Problem-Solving Groups

Leonard M. Jessup

College of Business Administration
California State University, San Marcos
820 West Los Vallecitos Boulevard
San Marcos, California 92069

Terry Connolly

Department of Management and Policy
College of Business and Public Admin.
University of Arizona
Tucson, Arizona 85721

Abstract

A laboratory experiment was used to evaluate the effects of interaction frequency on computer-mediated groups using a Group Support System to perform an idea-generation task. Group interaction is defined here as the length of time group members are allowed to form and input their contributions and the related rate at which group members exchange their contributions. We found that frequently interacting groups and nominal groups outperformed infrequently interacting groups and individuals, but that frequently interacting groups felt more interrupted, less able to concentrate, and more hurried.

Introduction

Several computer-based information system technologies have been developed to aid group work (for discussion see Johansen, 1988; Kraemer & King, 1988; Pinsonneault, & Kraemer, 1989). One such technology, Group Support Systems (GSS), combines communication, computer and decision technologies to support intellectual, goal-directed, collaborative work (for discussion see Jessup & Valacich, 1993). As of yet, no general guiding theory of GSS has emerged (Valacich, Jessup, Dennis & Nunamaker, 1992). The primary reason for the difficulty in developing a comprehensive theory is that there is a multitude of dimensions on which these systems can be configured and used. The study of GSS includes, group size, member proximity, whether the communication is synchronous or asynchronous, the degree of structure of the group process, the amount of electronic communication, which communication channels are utilized, the physical layout of the room, types of user interfaces, hardware platforms, and so on (for recent discussion, see Nunamaker, et al., 1991A).

Because of the multi-faceted, complex nature of GSS, Huber (1990) suggested that researchers should more precisely define and measure these technologies, because subtle system differences may have profound effects. Accordingly, several researchers have now begun to isolate, manipulate, observe and compare various components of GSS. For example, a stream of GSS research is now focussed on GSS anonymity (see, for example, published articles by Connolly, Jessup & Valacich, 1990; George, Easton, Nunamaker, & Northcraft, 1990; Jessup, Connolly, & Galegher, 1990; Jessup, & Tansik, 1991; Valacich, Dennis, & Nunamaker, 1992; Valacich, Jessup, Dennis & Nunamaker, 1992).

Surprisingly, other important GSS components have not yet been studied to the extent that the anonymity component has been studied. For example, the design of brainstorming software, perhaps the most used component of traditional GSS, rests on assumptions of group idea generation from GSS field observations and from previous studies of non-automated individual and group idea generation. There has been little published empirical work on the design of brainstorming software.

The purpose of this paper is to investigate the engineering of the automated brainstorming process. Specifically, this paper reports on an experimental investigation of several forms of automated brainstorming. The primary contribution of this paper is that it helps us to better understand how we ought to engineer the automated brainstorming process. In the next section we summarize previous relevant research and pose our research questions. We then present our research design and results and draw conclusions.

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Prior Research

Two espoused advantages of GSS are: 1) the systems enable parallel processing of group member inputs (or at least sequences of interaction other than the traditional process of one person talking while n - 1 listen), and 2) the systems provide a structured approach to the group's work (Valacich, Jessup, Dennis & Nunamaker, 1992). However, there has been little empirical research to date that helps us to explain how or why processing and/or structuring of group member contributions and tasks ought to occur in electronic interaction. Considering that a great deal of GSS use involves electronic brainstorming, it is critical that we understand the optimal processing of member contributions and the optimal session structure.

We know a fair amount about individual and group idea generation in non-automated environments. Group brainstorming, a technique invented by Alex Osborn in the mid 1950s, was designed to maximize group process by forbidding criticism, urging quantity rather than quality of ideas, and encouraging modification of and piggybacking on the ideas of others (Osborn, 1957). Dozens of related group processes have since been proposed (see Van Gundy, 1981, for a survey). Unfortunately, there is little evidence that any of these techniques actually work, in the sense of yielding more or better ideas than the same number of people working alone for the same period of time and then pooling their output. For non-automated group brainstorming, the best studied of these manual techniques, the evidence is now clear: individuals brainstorming alone and later pooling their ideas produce more ideas, of a quality at least as high, as do the same number of people brainstorming face-to-face in a group (McGrath, 1984). Diehl and Stroebe (1987) suggest three possible reasons: a) People may be shy about proposing wild ideas in front of others and thus hold back ideas (evaluation apprehension); b) Group members see little connection between their efforts and the group output as a whole and therefore make less effort to contribute (free riding); c) In groups, only one person can talk while the others listen (or at least wait for their chance to talk), thus participants may forget or be talked out of ideas before they get a chance to propose them (production blocking). Though there is evidence that all three processes operate, Diehl and Stroebe conclude that production blocking is the main villain.

This conclusion is consistent with our own findings in GSS experiments. One of the tools available to us is an idea-generation support system called EBS (Electronic Brainstorming). In using EBS, a participant sits at a terminal that shows the theme question at the top of the screen (e.g., "What could be done about the campus parking problem?"). The user types in a suggestion (up to five lines) and sends off the file, which is immediately replaced by another file containing the same question and a suggestion offered by another participant. The first participant adds a comment, sends the file, receives another randomly drawn file, and so on, until the session is concluded. As the file builds, the user can scroll to and fro through the comments. Thus, whereas someone noting ideas on a wordprocessor has only his or her own earlier ideas to look back on, the EBS participant can look back on a loosely-knit chain of ideas generated by others. The hypothesis is that this chain of ideas will provide enough stimulation to generate useful new ideas without incurring the "production blocking" costs associated with normal face-to-face interaction.

This hypothesis has received substantial support, at least for large groups, from a recent series of experiments with the EBS system (Valacich, Dennis, & Connolly, in press). Using a variety of problems, group sizes, incentives and input formats, Valacich, et al found that EBS groups larger than a dozen or so members generated more ideas than did the same number of individuals brainstorming on their own and later pooling output. Given a thirty-year history of precisely the opposite result from face-to-face group brainstorming, the results of the Valacich, et al experiments are exciting and need to be further understood and extended.

The purpose of this study is to extend that work to include the file-passing procedure that is used in the automated brainstorming process. As argued above, it is critical that we understand automated brainstorming so as to optimize the process. Of interest here is the interaction frequency used in the process. We define interaction frequency as the length of time group members are allowed to form and input their contributions and the related rate at which group members exchange their contributions.

Whereas the previous experiments were designed to investigate the relative performance of nominal and interacting groups, with other elements of group process held constant, this study is designed to investigate group process more closely. The general question driving this study is, "How best can automated groups work together to generate ideas?" One subsequent, pragmatic question is, "How should we engineer group brainstorming software?" Thus, our research question is," What are the effects of GSS interaction frequency on idea generation?"

To answer this research question we present a continuum of interaction frequency (see Figure 1). At one extreme is constant interaction (e.g., Osborn's "brainstorming"), where group members quickly generate ideas with little or no time for evaluation of ideas. The primary advantage is that members "piggyback" off each others' ideas. Connolly, Jessup and Valacich (1990) provide evidence that such intellectual prodding helps the idea generation process. The primary disadvantage to constant interaction is classic production blocking. At the other extreme is no interaction, where individuals work alone and, possibly, later pool their ideas (e.g., Van de Ven's Nominal Group Technique). The advantage is deliberation; each group member can completely expend his or her own solution set with no interruptions. The disadvantage is that piggybacking cannot occur. An elusive idea will not be "jarred" loose by the input of another group member. Gettys and colleauges (Gettys and Fisher, 1979; Gettys, Pliske, Manning, & Casey, 1987) provide evidence to suggest that in some settings individuals working alone produce only a tiny fraction of the available solution space.

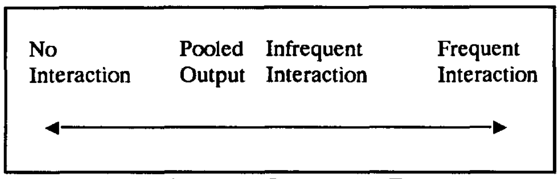

Figure 1 A continuum of Interaction Frequency

In between these two extremes are situations where the rate of interaction frequency varies, from frequent interaction to infrequent interaction among group members. We believe that in this middle ground lies an optimal process, where group members achieve the best of both worlds - deliberation and collaboration. Members can deliberate and expend their own solution set (or at least some portion of it) and then exchange contributions and continue the process, "jarred" by new information from other members. GSS technologies make such intermediary brainstorming processes feasible. Thus, we hypothesize that automated brainstorming groups operating under conditions of infrequent, punctuated interaction will be more effective at generating ideas than will groups with more frequent interaction, nominal groups, or individuals working alone.

Research Design

Task and Equipment

The GSS software for the experiment was a networked version of WP51 within the IBM IClass system, running on Novell Netware, installed at the California State University, San Marcos Computing Center. The installation includes 8 individual workstations arranged in a U-shaped configuration.

The file sharing process used with this software was designed to mimic the process used with the EBS software used in the Connolly et al experiment described above. IClass enabled the participants to easily share files via a structured process using a networked version of WP51. The subjects were required to demonstrate competency in WP51 as part of their program of study, so all subjects were able to use the system easily.

The task used in this experiment was exactly the same as that used in the Connolly et al experiment, the generation and evaluation of possible solutions to the University's parking problems. As in the Connolly et al experiment, this task was chosen here because it generates high involvement in student subjects and draws on their personal knowledge. Further, the parking problem task has been extensively explored by other researchers (see Gettys, Pliske, Manning, and Casey, 1987), which facilitates coding of group outputs.

Subjects

Fifty-four upper-division business students satisfying a course requirement for experimental participation served as subjects. The sample was evenly split between juniors and seniors, and between men and women. They were drawn from a business student population where the average age is 29 and nearly all students have work experience. They were randomly assigned into the experimental conditions described below.

Design

A one-way, four-factor design was used, with conditions of: 1) individuals working alone, 2) manufactured nominal groups, 3) interacting groups with infrequent interaction, and 4) interacting groups with frequent interaction (see Figure 2). The system left participants' contributions unidentified. No efforts were made through experimental procedures to either identify subjects or insure anonymity.

In the first condition, individuals worked alone for forty minutes, with no interaction with other subjects. For the second condition, three-person groups were manufactured by randomly selecting the output of individuals from the first condition. Thus, the output of nominal groups in the second condition represented the output of three individuals working independently for forty minutes each. For the third condition, subjects were randomly assigned to work together in interacting groups of three members each. These three-person, interacting groups spent a total of forty minutes actually working on the problem together (not including a few seconds for file passing). They exchanged files every ten minutes, for a total of three file passes during their session (passing files at the 10, 20 and 30 minute mark, and then ending the process at the 40 minute mark). As in the third condition, subjects in the fourth condition were randomly assigned to work together in interacting groups of three members each. These three-person, interacting groups also spent a total of forty minutes actually working on the problem together. However, they exchanged files every two minutes, for a total of nineteen file passes (beginning at the two minute mark and then passing files every two minutes, until finally ending the process at the forty minute mark).

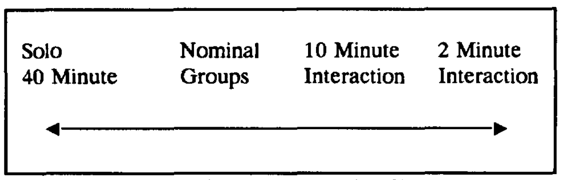

Figure 2 Manipulation of Interaction Frequency

A total of twelve individuals participated in the first condition (individuals). Thirty three-person groups were manufactured for the second condition (nominal groups). Seven three-person groups participated in the third condition (infrequently interacting groups) and another seven three-person groups participated in the fourth condition (frequently interacting groups).

<u>Procedure</u>

On reporting to the experimental site, subjects were assigned to their work stations. The experimenter read aloud the experimental instructions, while the subjects followed along with their own copies. The parking problem was described to them, and they were asked to spend 40 minutes generating possible solutions using the system. The instructions reminded them that there are many different possibilities for dealing with campus parking, and urged them to try to generate as many "creative, workable" solutions as they could. They were told that their plans would eventually be reviewed by a panel of experts who would rate them for quality and assign a final score. The instructions imply that both quantity and quality of ideas were sought. The operation of the system was then described to the subjects. Subjects did not have any difficulty understanding this, and none asked for further clarification of the task objective or system operation. After 40 minutes of work the subjects completed a brief post-experimental questionnaire and were debriefed and released.

Results

<u>Content Coding</u>

For this study, we followed the content coding scheme used by Connolly et al and others (see, for example, Jessup, Connolly, & Galegher, 1990; Jessup, & Tansik, 1991; Valacich, Dennis, & Nunamaker, 1992). The files produced by subjects were first independently coded by two raters who were blind as to experimental conditions and hypotheses. Each rater first parsed a paper transcript of the file to indicate what he/she judged to be separate ideas, comments or suggestions. He/she then assigned to each parsed unit a code derived from the scheme (e.g., proposed solution, supportive remark, supportive argument, critical remark, critical argument, solution clarification, problem clarification, question about solution, question about problem, comment about the system, comment about the group, comment off the topic or uncodable text). After completing these codings independently, the initial two raters met and discussed both parsings and codings to consensus. A third rater helped to negotiate disagreements. This process resulted in a mean of 51.36 parsed, coded units (comments) per group. Both coding and parsing processes achieved adequate inter-rater reliabilities, with ratios matching those in previous studies (approximately 93% initial parsing and coding agreement).

<u>Manipulation Checks</u>

There were no mishaps in exchanging files for any of the subjects, either in loss of time or misplaced files. File exchanges occurred correctly and at the predetermined time in every case.

One group, in the "frequently interacting" condition, was dropped from the analysis. In this group, the members degenerated into complete silliness and generated useless comments. At first one group member contributed silly comments that were off the topic. Eventually a second group member engaged in the frivolous commentary. The third group member pleaded that the other two group members return to the task, but then gave in, joining in the frivolity. Interestingly, amid the silliness within this group, some comments were caustic, and were directed not at each other (group member) but rather at issues external to the group (e.g., at administrative issues within the business program). The pattern of comments generated by this group was so atypical that we judged it best to drop them from the analysis. The general pattern of the measures after dropping this group is discussed below.

Substantive Findings

Table 1 provides descriptions of the dependent variables from the content coding of the subjects output. Table 2 provides descriptive statistics for these dependent variables. The analysis summarized in Table 3 confirms that the manipulation of interaction frequency had significant effects on the output of these subjects. A one-way analysis of variance showed significant differences on our three primary measures of productivity - total comments generated, total ideas generated, and original ideas generated (total ideas stripped of redundancies) and on nearly every other comment subcategory.

totcom =	total comments
totidea =	total workable ideas
origidea =	total workable, original ideas
suprem =	supportive remarks
suparg =	arguments
totsup =	total supportive remarks and arguments
critrem =	critical remarks
critarg =	critical arguments
totcrit =	total critical remarks and arguments
probclar =	problem clarifications
solclar =	solution clarifications
totclar =	total problem and solution clarifications
quessol =	question about solution
quesprob =	question about problem
totques =	total questions about problems and solutions
comcomp =	comments about the system
comgrup =	comments about the group
ott =	comments off the topic
uc =	uncodable text
tototh =	total of comments about system and group, comments off the topic, and uncodable text

Table 1 Descriptions of dependent variables from content coding.

A Least Significant Differences multiple comparison test (significance level set at 0.05) was used to explain the differences between conditions for the independent variables. This analysis found that nominal and interacting groups outproduced individuals, with groups in the frequently interacting condition producing the highest number of total comments during their sessions. The significant differences between treatments for the total number of ideas are identical to those for total comments. The results for the total number of original ideas produced are slightly different. Here, nominal and interacting groups outperformed individuals, and while nominal and frequently interacting groups outperformed infrequently interacting groups, the difference between the performance of nominal and frequently interacting groups is not significant at the 0.05 level.

Variable	Mean	Std Dev	Min	Max
totcom	51.36	26.87	10.00	137.00
totidea	23.87	15.48	3.00	101.00
origidea	20.68	10.23	3.00	52.00
suprem	3.20	4.33	.00	16.00
suparg	4.38	4.29	.00	19.00
totsup	7.57	7.71	.00	31.00
critrem	2.30	4.10	.00	27.00
critarg	2.23	3.35	.00	16.00
totcrit	4.54	7.00	.00	43.00
probclar	2.18	3.82	.00	23.00
solclar	12.36	7.04	1.00	25.00
totclar	14.00	7.87	1.00	31.00
quessol	.45	1.25	.00	6.00
quesprob	.05	.40	.00	3.00
totques	.50	1.53	.00	9.00
comcomp	.00	.00	.00	.00
comgrup	.14	.70	.00	5.00
ott	.13	.38	.00	2.00
uc	.54	1.53	.00	8.00
tototh	.80	2.27	.00	11.00

Table 2 Descriptive statistics for dependent variables from content coding (N = 56).

To the extent that these measures assessed "effective idea generation," they offer only partial support for our hypothesis that infrequently interacting groups would be more effective at idea generation that

	(N=12) Individuals		(N=30) Nominals		(N=7) Infrequent Interaction		(N=7) Frequent Interaction		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Sign.
totcom	18.58	5.17	52.40	7.61	50.14	19.04	104.28	22.41	**
totidea	8.50	3.70	24.70	5.45	25.42	16.92	45.14	27.09	**
origidea	8.41	3.55	24.43	5.17	16.71	12.68	29.57	12.83	**
suprem	0.58	1.24	1.76	2.12	4.00	2.30	13.00	2.30	**
suparg	1.33	1.77	3.73	3.24	6.42	3.69	10.28	5.67	**
totsup	1.91	2.27	5.50	4.39	10.42	4.27	23.28	6.36	**
critrem	0.50	0.90	1.26	1.14	2.57	1.90	9.57	8.30	**
critarg	0.33	0.77	1.06	1.14	5.57	3.45	7.14	5.33	**
totcrit	0.83	1.58	2.33	2.08	8.14	5.01	16.71	12.59	**
probclar	0.83	1.46	3.06	4.89	1.00	1.52	1.85	1.57	-
solclar	6.41	2.84	17.73	4.32	3.00	2.23	8.85	3.57	**
totclar	7.25	3.51	19.80	5.17	4.00	2.94	10.71	4.30	**
quessol	0.00	0.00	0.00	0.00	1.14	1.06	2.42	2.57	**
quesprob	0.00	0.00	0.00	0.00	0.00	0.00	0.42	1.13	?
totques	0.00	0.00	0.00	0.00	1.14	1.07	2.85	3.38	**
comcomp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
comgroup	0.00	0.00	0.00	0.00	0.14	0.37	1.00	1.82	**
ott	0.00	0.00	0.00	0.00	0.28	0.48	0.71	0.75	**
uc	0.00	0.00	0.00	0.00	0.42	0.53	3.85	2.47	**
tototh	0.00	0.00	0.00	0.00	0.85	0.69	5.57	3.95	**

Table 3 Content coding of group output files (by conditions). For significance: ?, $p < 0.10$; *, $p < 0.05$; **, $p < 0.01$.

would groups with more frequent interaction, nominal groups, or individuals working alone. The infrequently interacting groups in this study outperformed individuals working alone, but these groups did not outperform nominal groups or frequently interacting groups.

Closer inspection of the comment categories in Table 3 shows that for many categories the pattern mirrored that for total comments. Nominal and interacting groups made more supportive and critical remarks and arguments than did individuals, and interacting groups did more of this than did nominal groups ($P < 0.05$). Furthermore, frequently interacting groups did more of this than did infrequently interacting groups ($P < 0.05$). Similarly, interacting groups asked more questions about problems and solutions and made more comments about the system, the group and about ancillary issues, than did nominal groups ($P < 0.05$). Finally, frequently interacting groups asked more questions overall than did infrequently interacting groups ($P < 0.05$).

A cluster of measures on the post-experimental questionnaire tapped participants' perceptions with various aspects of their experience (see Table 4 for descriptions and Table 5 for descriptive statistics). A one-way analysis of variance showed significant differences on six questionnaire items that measured perceptions of the adequacy of time given for idea generation. On a seven-point scale anchored at 1, "Not enough time," and 7, "Plenty of time," frequently interacting groups expressed themselves as not having as much time with each file to effectively generate and evaluate ideas (Q1) or to digest ideas and comments from other members (Q2) as did infrequently interacting groups ($P < 0.05$). Three questionnaire items asked subjects to circle the response that best described their work. On a seven-point scale anchored at 1, "many interruptions, and 7, "no interruptions," and on a seven-point scale anchored at 1, "not able to concentrate, and 7, "easily able to concentrate," frequently interacting groups expressed themselves as having more interruptions (Q7) and being less able to concentrate (Q8) than did infrequently interacting groups, nominals and individuals ($P < 0.05$). On a seven-point scale anchored at 1, "did an incomplete job," and 7, "did a thorough job," interacting groups expressed themselves as performing a less thorough job (Q9) than did individuals and nominal groups ($P < 0.05$).

Q1	=	given enough time with each file to effectively generate and evaluate ideas.
Q2	=	given enough time to digest ideas and comments from other members
Q3	=	inputs from other members helpful
Q4	=	given enough time overall to effectively generate and evaluate ideas
Q5	=	work slow or fast
Q6	=	work hurried or leisurely
Q7	=	many interruptions or no interruptions
Q8	=	not able to concentrate or easily able to concentrate
Q9	=	did an incomplete job or did a thorough job
Q10	=	possible for others to identify comments
Q11	=	possible for group members to identify comments
Q12	=	satisfied with computer system
Q13	=	satisfied with the process
Q14	=	satisfied with ideas proposed
Q15	=	satisfied with evaluations of ideas
Q16	=	satisfied with experience overall
Q17	=	willing to work again with group
Q18	=	effective at using group members' resources
Q19	=	effective at generating ideas
Q20	=	effective at evaluating ideas
Q21	=	system helpful in completing task
Q22	=	as effective as traditional face-to-face process
Q23	=	importance of parking problem at university
Q24	=	importance of parking problem to you

Table 4 Descriptions of questionnaire items.

Oddly, on a seven-point scale anchored at 1, "very slow," and 7, "very fast," individuals and nominalgroups expressed themselves as working faster (Q5) than did interacting groups ($P < 0.05$). The analysis of variance detected no significant differences on other questionnaire items measuring participants' satisfaction or perceived effectiveness.

Discussion

The findings of this study can be quickly summarized. Subjects worked on an idea-generating task individually and in groups using an automated brainstormingsystem. Nominal and interacting groups outproduced individuals, with groups in the frequently interacting condition producing the highest number of total comments and total ideas during their sessions. Nominal and interacting groups produced more original ideas than did individuals, and nominal and frequently interacting groups produced more original ideas than did infrequently interacting groups. A closer inspection of the comment categories revealed that frequently interacting groups tended to make more supportive and critical remarks and arguments, ask more questions about problems and solutions, make more comments about the system, the group and about ancillary issues, and ask more questions overall than did individuals, nominals and infrequently interacting groups.

Contrary to our reasoning, infrequently interacting groups in this study did not outperform nominal groups or frequently interacting groups. Indeed, frequently interacting groups and nominal groups clearly outperformed infrequently interacting groups. Interestingly, the gains in performance displayed by the frequently interacting groups contradict their responses to post-experimental measures of process and outcome. Interacting groups expressed themselves as performing a less thorough job than did individuals and nominal groups. Frequently interacting groups expressed themselves as having more interruptions and being less able to concentrate than did infrequently interacting groups, nominals and individuals. Finally, frequently interacting groups expressed themselves as not having as much time with each file to effectively generate and evaluate ideas or to digest ideas and comments from other members as did infrequently interacting groups.

	(N=12) Individuals		(N=30) Nominals		(N=7) Infrequent Interaction		(N=7) Frequent Interaction		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Sign.
Q1					5.28	0.48	4.0486	1.35	*
Q2					5.47	0.74	4.0957	1.00	*
Q3					5.28	0.93	5.570	0.97	-
Q4	6.58	0.90	6.46	0.52	5.52	0.57	5.0457	1.49	**
Q5	4.91	0.79	4.95	0.45	4.57	0.41	4.9029	0.81	-
Q6	4.81	1.53	4.81	0.71	4.09	0.76	3.0000	0.63	**
Q7	6.18	1.16	6.21	0.54	5.83	0.85	4.6657	0.69	**
Q8	5.16	1.64	5.35	0.96	5.35	0.49	5.1443	0.71	-
Q9	5.54	0.93	5.71	0.43	4.93	0.79	4.5714	1.22	**
Q10	2.16	0.71	2.05	0.36	2.00	0.42	1.7614	0.37	-
Q11					2.66	0.27	2.2871	0.59	-
Q12	5.41	1.72	5.35	0.87	6.33	0.38	5.6200	1.02	-
Q13	5.50	1.08	5.48	0.50	5.73	0.74	5.5700	0.97	-
Q14	5.50	0.90	5.50	0.38	5.19	0.54	5.1429	0.95	-
Q15	5.00	1.05	4.74	0.63	4.95	0.70	5.1414	0.91	-
Q16	6.00	0.73	5.96	0.40	5.52	0.90	5.5700	0.85	-
Q17					5.57	0.91	5.4757	1.29	-
Q18					5.13	1.14	5.0943	1.08	-
Q19	5.44	0.72	5.54	0.46	5.32	0.97	5.620	0.75	-
Q20	5.00	1.06	5.08	0.76	4.85	0.81	4.904	1.14	-
Q21	5.50	1.24	5.42	0.58	5.85	0.50	5.715	0.93	-
Q22	5.41	1.88	5.41	0.94	5.81	0.57	6.190	0.57	-
Q23	6.66	0.77	6.62	0.45	6.24	0.56	6.240	0.46	-
Q24	5.83	1.03	5.81	0.48	5.66	1.21	5.810	0.99	-

Table 5 Questionnaire data (by conditions). For significance: ?, $p < 0.10$; *, $p < 0.05$; **, $p < 0.01$.

Responses to an open-ended question on the post-experimental questionnaire display an interesting pattern which may give a clue as to the nature of the conditions. The last item simply stated, "Any comments?" Of the 21 subjects participating in the infrequently interacting condition, there were eight very positive responses, one somewhat negative response, and one suggestion about the task. The following response spoke directly to the experimental manipulation: "This was an excellent way to brainstorm ideas. People did not interrupt the flow of ideas and there was time to think about each proposal before responding." Of the 21 subjects participating in the frequently interacting condition, there was only 1 positive response, 2 negative responses, one somewhat negative response, and one comment about the ideas generated during the session. Two responses spoke directly to the experimental manipulation: 1) "Even though they were 2 minute frames, I feel we had good ideas. I think the time pressure made me think harder." and, 2) "Not enough time. Very tedious." Of the twelve subjects participating in the individual condition, only two gave written responses: one was about the parking problem and one was about the questionnaire.

Subject responses on a follow-up questionnaire, which was not required, two to four weeks after the experiment display a theme that is similar to that in the comments on the post-experimental questionnaire. Twenty-seven of the fifty-four subjects completed the follow-up questionnaire. Participants in the infrequently interacting condition generally made positive remarks about their sessions, particularly about being able to leisurely exchange ideas with other group members. Participants in the frequently interacting condition also made some positive remarks about their sessions, but many of them focused their remarks on the pressure induced by the frequent file exchanges, with some speaking to the positive effects of the pressure and some speaking to the negative effects.

These comments fit the pattern in the statistical results described above. The more leisurely pace of the infrequently interacting groups appeared to be better received by the group members than was the hurried, haphazard pace of the frequently interacting groups. However, despite the hectic pace, groups in the frequently interacting condition outperformed infrequently interacting groups. These results mirror those in the Connolly et al (1990) study in two ways. First, subjects' perceptions of the effectiveness of the process contradict more objective measures of outcome. Subjects in the frequently interacting groups expressed themselves as having more interruptions, as being less able to concentrate, and as not having as much time with each file to effectively generate and evaluate ideas or to digest ideas and comments from other members. However, they clearly outperformed subjects in infrequently interacting groups. Second, it appears that the intellectual prodding induced by the pressure of frequent file exchanges spurred the groups to better performance.

While these results contradict our theorizing that prolonged, individual deliberation coupled with collaboration would be best for automated brainstorming, the results support conventional wisdom that hurried, spontaneous exchanges are better. Similarly, because our small, interacting groups did no better, statistically, then nominal groups at generating ideas, these results support the findings of Valacich et al (in press) that interacting groups do not outperform nominal groups until group size becomes larger.

Given the surprising performance of the nominal groups in this study and the conclusions of Valacich et al that only larger interacting groups outperform nominal groups, one clear extension to this study is to replicate it with larger groups. We may find that the effects of interaction frequency change as groups get larger, or we may find that frequent exchanges work better regardless of group size. Either way we will have learned something valuable about how to maximize the brainstorming potential of automated groups.

It is possible that our theorizing about interaction frequency was right while our experimental manipulations and measures of the construct were wrong. We operationalized frequent interaction as two minute file exchanges between group members. Based on our experiences with GSS brainstorming and our interpretations of the brainstorming literature this pace of exchange made sense. However, our operationalization of infrequent interaction as ten minute file exchanges between group members was in part a result of our logistical constraints and was, admittedly, somewhat arbitrary. It may be that to realize the gains from individual deliberation group members need to independently spend more time muddling through the problem and the solution space, perhaps 30 minutes, an hour, twenty-four hours, or more. Thus, one other extension to this study is to manipulate interaction frequency so as to test different rates of exchange, particularly longer periods of individual deliberation. Given the growth in research on and development of different time / different place GSS, investigations of prolonged group member interaction via GSS will be feasible and useful. We may find, for example, that it is best to give group members plenty of lead time on a problem so that they can brainstorm via GSS from their desktop PCs in their office for a week or so prior to a face-to-face meeting. This way members can think about a problem and its solutions for a day or two on their own, exchange ideas electronically with other members working from their own offices, and then repeat the process, perhaps several times, until the stated meeting time.

This experiment is clearly limited in some important ways. The subjects were students, with no significant stakes in the outcome of their work, less than an hour to work on the task was required, and only fourteen three- person groups and twelve individuals were available. Replication and extension of this study are needed. We believe that this study provides useful information about interaction frequency, and we believe generally that laboratory experimentation with student subjects has a useful role to play in an overall research program on GSS. However, we are sensitive to the weaknesses in external validity to this type of

We began the introduction by noting that GSS are multi-faceted and complex and, therefore, GSS researchers need to more precisely define and measure important elements of the technology. Thus, we support the view that we need to establish the empirical base for a contingency theory of GSS that identifies what it is about GSS that makes them effective. To that end, the focus of this study was interaction frequency, one important part of the GSS brainstorming process. We found that frequently interacting groups and nominal groups outperformed infrequently interacting groups and individuals, but that frequently interacting groups felt more interrupted, less able to concentrate, and more hurried. We look forward to extending this research to larger groups and different paces of group member interaction.

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