© Academy of Management Journal
1992, Vol. 35, No. 2, 350–369.

ELECTRONIC BRAINSTORMING AND GROUP SIZE

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Two concurrent experiments were conducted with groups of varying size; there were 2-, 4-, and 6-person groups in one and 6- and 12-person groups in the other. We compared the number and quality of unique ideas generated by groups of each size using electronic and nonelectronic, verbal brainstorming. Groups used both techniques in a counterbalanced within-group design. The larger groups in both experiments generated more unique ideas and more high-quality ideas, and members were more satisfied when they used electronic brainstorming than when they used verbal brainstorming. There were fewer differences between the two techniques for the smaller groups in each experiment. We interpret these results as showing that electronic brainstorming reduces the effects of production blocking and evaluation apprehension on group performance, particularly for large groups.

One of the more common tasks for groups in organizations is generating ideas. Design teams, marketing groups, task forces, and program committees are all examples of organizational groups that generate ideas. Because of the importance of idea generation, a great deal of effort has been devoted to finding techniques that can help the process work more effectively. Brainstorming, a group idea-generation technique that has been used for over 35 years, is widespread. It has high face validity, its rules are easy to under-

This research was supported by a grant to the first and third authors from the Social Sciences and Humanities Research Council of Canada (#410-90-0786) and by grants from IBM, AT&T, and the National Science Foundation. We thank Viki Young and Lesley McCallum for scoring the main dependent variable.

stand, and many participants experience the kind of synergy that is supposed to be the technique's main advantage. That is, some people do hear ideas that prompt them to think of other ideas of which they might not have otherwise thought. As a result, brainstorming has strong appeal as a way for groups to generate ideas.

One problem with traditional brainstorming is that large groups typically do not generate more ideas than small groups, and it has become generally accepted that large brainstorming groups are not productive. This research investigated a technique called electronic brainstorming and attempted to determine if it can more effectively support the idea generation tasks of both large and small groups than the traditional brainstorming technique.

BRAINSTORMING

The history of research on brainstorming consists of two distinct streams. The first assesses the effectiveness of the original brainstorming technique, and the second tests a variety of newer methods of idea generation. Both streams owe their origins to the 1954 publication of Osborn's *Applied Imagination*. Osborn described the group brainstorming technique and presented persuasive examples of how brainstorming could be used to help groups generate ideas. His central theme was that groups can generate more ideas if their members concentrate on producing whatever ideas occur to them while avoiding evaluation of their own and other's ideas. Evaluation is to be done at a later stage.

Taylor, Berry, and Block (1958) launched the first type of research by testing Osborn's claim that groups using brainstorming could generate more ideas than the same number of individuals working separately, a configuration that those authors named a "nominal group." This stream was strongest in the 1960s and dissipated in the late 1970s, by which time researchers had lost interest in repeated demonstrations that brainstorming groups produced fewer nonredundant ideas than did equivalently sized nominal groups.

A secondary question within this stream was whether group size made a difference in the effectiveness of brainstorming groups. Osborn argued that brainstorming was most effective for groups of up to 12 members. Leading research journals have published seven group-size studies of brainstorming (Bouchard, Drauden, & Barsaloux, 1974a,b; Bouchard & Hare, 1971; Fern, 1982; Hackman & Vidmar, 1970; Lewis, Sadosky, & Connolly, 1975; Renzulli, Owen, & Callahan, 1974). All of the preceding except Renzulli and colleagues (1974) found that large groups did not generate more ideas than small groups. Renzulli and colleagues found that 12-member groups did generate more ideas than 3-member groups. All seven studies found that the number of ideas generated per person declined as the size of the group increased. Thus, there is consensus from this first stream of research that brainstorming groups do not outperform their nominal group counterparts and that the marginal productivity of members of brainstorming groups declines as groups grow larger.

The second stream of research focuses on the development and testing of new techniques for idea generation. Many structured techniques have been developed, including the delphi technique and the nominal group technique (which differs from nominal groups as they are defined above; cf. Delbecq, Van de Ven, & Gustafson, 1975; Van Gundy, 1981, 1987). Many studies have been published comparing the effectiveness of these techniques to Osborn's brainstorming technique. Although some studies have shown that these structured techniques can improve idea generation, most have found that groups using them do not generate more ideas than groups using traditional brainstorming or unstructured group interaction (e.g., Hegedus & Rasmussen, 1985; Jablin & Seibold, 1978; Lamm & Trommsdorff, 1973).

Research has suggested two primary reasons why nominal groups outperform interacting groups, structured idea generation techniques provide little advantage over unstructured interaction, and large groups do not generate more ideas than small groups (e.g., Diehl & Stroebe, 1987; Jablin & Seibold, 1978; Lamm & Trommsdorff, 1973). The two problems identified are production blocking and evaluation apprehension. Production blocking occurs when individuals cannot express their ideas because someone else is talking. Thus, production blocking can cancel out or override the synergistic effects that brainstorming is supposed to produce. This problem can be overcome if group members can simultaneously produce their ideas. Evaluation apprehension occurs when individuals withhold their ideas out of concern that others may not approve of them. The lack of anonymity in brainstorming groups reduces the likelihood that novel ideas will be generated. Evaluation apprehension may be particularly likely to occur for low-status members of groups that include dominant, high-status members. It can be overcome by ensuring anonymity. In addition to production blocking and evaluation apprehension, other inhibitors, such as social loafing (Latané, Williams, & Harkins, 1979), may be likely present in brainstorming group interaction. Moreover, the magnitude of inhibitors may grow as group size increases (Steiner, 1972).

ELECTRONIC BRAINSTORMING

The research reported in this study continued the second stream of research on brainstorming by examining a new technique, electronic brainstorming, while returning to the group-size issue important in the first stream. In electronic brainstorming, group members can simultaneously type ideas into a computer that then distributes the ideas to the screens of other group members.[1] Our experience with electronic brainstorming is that members access the ideas produced by the group, particularly when they run out of ideas. Although interaction in the form of verbal comments and ex-

[1] Electronic brainstorming was implemented using an electronic meeting-support system called the University of Arizona GroupSystems. See Nunamaker and colleagues (1991) for more information.

pressions of affect is absent, there is interaction in that people build on the ideas of co-members and combine their ideas with others'. Because of this interaction, electronic brainstorming resembles traditional brainstorming without having its drawbacks.

The electronic brainstorming process combines an aspect of the nominal group process—being able to generate ideas at will—and an aspect of the traditional brainstorming process: being able to share ideas with others. Synergy can occur in electronic brainstorming groups through the sharing of ideas by way of the computer screen. Observations and participants' comments after the electronic brainstorming sessions in a previous brainstorming study (Gallupe, Bastianutti, & Cooper, 1991) indicated that the participants were not distracted by the ideas on the screen. They seemed to process these ideas very fast, studying them when they could not think of another idea on their own. Observations made in the previous study indicated that individuals generated a number of ideas quickly at the start of a session, then experienced a lull during which they seemed to be processing other group members' ideas. Another burst of idea generation, smaller than the first, follows, then another lull occurs. This process is repeated until the session ends.

Electronic brainstorming may reduce the effects of production blocking because, since members can work simultaneously, they are not blocked from contributing ideas. Furthermore, all ideas are anonymous, which may reduce the inhibiting effects of evaluation apprehension (Connolly, Jessup, & Valacich, 1990). Indeed, Gallupe and colleagues (1991) showed that 4-person electronic brainstorming groups outperformed verbal brainstorming groups of the same size. Our questions in the present research were whether the superiority of electronic brainstorming groups would increase with group size, and whether the electronic advantage would decrease for groups smaller than 4 members.

Because production blocking and evaluation apprehension are likely to increase with group size for nonelectronic brainstorming groups, but not for electronic brainstorming groups, we expected that the superiority of electronic brainstorming would grow as group size increased. Indirect support for this prediction is found in Dennis, Valacich, and Nunamaker (1990); they found that 18-member electronic brainstorming groups generated more ideas than 9-member electronic brainstorming groups, which in turn generated more ideas than 3-member electronic brainstorming groups. This support is only indirect because no nonelectronic brainstorming groups were used for comparison. Our expectations about a group-size effect were based on six of the seven previous studies of nonelectronic brainstorming and group size. These studies did not find an effect for group size and, accordingly, we did not expect to find a difference in productivity linked to group size. We express our expectations in two hypotheses:

> *Hypothesis 1: Electronic brainstorming groups will outperform nonelectronic brainstorming groups for all sizes of groups. That is, technology will have a main effect.*

Hypothesis 2: There will be no difference in the productivity of nonelectronic brainstorming groups of different sizes, but large electronic brainstorming groups will be more productive than small ones. That is, the interaction of technology and group size will be significant.

This study, which builds on and extends the work of Gallupe, Dennis, and their respective colleagues, was part of an ongoing research program on electronic brainstorming conducted at Queen's University and the University of Arizona. Gallupe and colleagues' study, the initial experiment to determine if electronic brainstorming was better than traditional brainstorming for groups of a fixed size (4 people), was the first study to compare technologically unsupported brainstorming groups with supported groups. It used small groups and therefore may not have demonstrated the true potential of electronic brainstorming. Dennis and colleagues only compared supported groups of varying sizes and did not include baseline unsupported groups to allow direct comparisons on the tasks the groups were given. We designed the present study to address those deficits.

Two experiments were conducted concurrently to examine the effects of computer-mediated technology and group size on the productivity of brainstorming groups. We conducted the two experiments using the same design, technology, and procedures in two different settings: the Queen's University Decision Lab in Kingston, Ontario, and the Park Student Center Lab at the University of Arizona in Tucson. Experiment 1 (the Queen's experiment) used three group sizes (2, 4, and 6 members) and experiment 2 (the Arizona experiment) used two group sizes (6 and 12 members). We report the Queen's experiment first.

EXPERIMENT 1

Methods

Subjects. One hundred twenty undergraduate students (60 men and 60 women) enrolled in an organizational behavior course at Queen's University participated for partial course credit. Their mean age was 19.8 years. None had previously participated in a brainstorming study. Ten groups of each of the three sizes were studied; groups contained equal numbers of men and women.

Task. Two questions were used. One was a variant on the traditional tourism problem: "How can tourism be improved in Kingston?" The second was "How can campus security be improved at Queen's?" In addition, we used two practice questions: "What benefits and difficulties would occur if everyone grew an extra thumb on each hand?" and "What are some uses for a knife?"

Treatments. The two independent variables were group size and technology. We used a fully balanced repeated measures design. All groups performed both tasks. Half answered the tourism question first and half answered it last. All groups brainstormed using both electronic and nonelectronic brainstorming. Half the groups used electronic brainstorming first, and half used it last. During electronic brainstorming, group members entered ideas by typing them at individual computer work stations. Every time a group member entered an idea, another set of ideas that had been generated by members of the group appeared on the individual's screen. In addition, a group member could simply press the F10 key to see additional ideas without entering an idea. In contrast, during the nonelectronic brainstorming, group members simply said their ideas out loud. These were recorded on a single tape deck for subsequent transcription.

The three group sizes were chosen because they allowed a feasible test of the hypotheses, and previous brainstorming studies have used groups of these sizes (cf. Diehl & Stroebe, 1987,1991; Dennis, Nunamaker, & Vogel, 1991). We assigned subjects to groups based on their availability and assigned groups randomly to treatments.

Procedures. When subjects arrived at the Queen's University Decision Lab, they were seated around a U-shaped table at individual work stations, each consisting of a color monitor, keyboard, and microphone. An experimenter (one of four men and two women) then introduced himself or herself and each member of the group. After the subjects had signed a consent form and an agreement of confidentiality, they completed a presession questionnaire that assessed their age, prior computer experience, self-reported keyboarding speed, and attitudes toward working in groups and using computers. We collected the presession data as a check on the effectiveness of the random assignment to groups. The experimenter then explained the upcoming sequence of events and described the rules for brainstorming: the more ideas the better, the wilder the ideas the better, combine and modify previous ideas, and don't criticize ideas. Bouchard and Hare (1970) and Osborn (1954) give details of the rules we used.

The subjects then brainstormed one of the two randomly assigned practice problems for 5 minutes, using the technology they would use for the first main problem. After the brainstorming rules were reviewed, they received the first of the two randomly assigned main problems (campus security or tourism). Groups had 15 minutes to generate ideas. A postsession questionnaire was then administered to assess members' perceptions of production blocking, evaluation apprehension, and satisfaction.

After introduction of the technology the group would use for the second main problem, members brainstormed the second practice question for 5 minutes. Procedures were again reviewed, and the group then brainstormed the second main problem for 15 minutes. Experimenters then administered a second, identical postsession questionnaire, thanked subjects for their participation, and dismissed them. All subjects received a written debriefing.

Dependent variables. The primary dependent variable for this experiment was the number of nonredundant ideas each group produced. The ideas of all groups were typed in identical formats for subsequent coding. An experienced coder who was both treatment- and hypotheses-blind assessed the number of nonredundant ideas each group had produced using the coding rules of Bouchard and Hare (1970). A second coder, who was trained via a coding manual co-written by the experienced coder (Cooper, Bastianutti, Young, Gallupe, & McCallum, 1991), then rated the 60 group outputs. The level of interrater agreement was high ($r = .96$). The experienced coder's ratings were used as the measure of the main dependent variable.

Previous research on traditional brainstorming has failed to show differences in the quality of the ideas produced by brainstorming and nonbrainstorming groups. Quality may not have differed because the instructions given to the participants emphasized generating as many ideas as possible rather than producing ideas of high quality. We decided to assess the quality of ideas because the electronic brainstorming technology is new, and the anonymity it provides may affect quality. The same two coders who rated the numbers of ideas also assessed their quality, using the same method as Diehl and Stroebe (1987). Each group's nonredundant ideas were rated for originality and feasibility on five-point scales, and the two coders' ratings were defined as being in agreement if they were within one point of each other. The two raters agreed in 95 percent of the originality ratings and 93 percent of the feasibility ratings. We averaged the two ratings to produce a quality score on a five-point scale and determined an overall quality score by summing the average ratings for the unique ideas generated by each group. We determined the total number of high-quality ideas by defining a high-quality idea as having a rating of 3.5 or above on the combined five-point scale and totaling the number of ideas that met this standard. We chose the standard of 3.5 because it was slightly above the mean rating of a sample of 100 ideas randomly chosen from all the nonredundant ideas generated across treatments.

The data from the two postsession questionnaires were used in the subsidiary analyses to better understand the effects of production blocking and evaluation apprehension and to examine differences in the perceptions of the two technologies and of the three group sizes.

Results

A two-factor (technology by group size) analysis of variance (ANOVA) was conducted on responses to each question from the presession questionnaire to determine whether there had been any significant differences between the groups before the session began. No presession differences emerged.

All variables were analyzed in a mixed ANOVA. Group size was a three-level between-group factor, and technology was a two-level within-group factor. A preliminary analysis of the number of ideas generated for the two problems showed no significant difference ($F_{1,48} = 2.32$, n.s.). Similarly, when we assessed the impact of the order in which the technologies were presented on the number of ideas generated for the two problems, we again found no significant difference in the number of ideas generated ($F_{1,48} = .39$, n.s.). Accordingly, we did not include task or order in the subsequent analysis.

An ANOVA for the number of nonredundant ideas showed that all three effects were statistically significant. Table 1 shows the mean number of ideas generated in the six cells, and Table 2 reports the F-values. As predicted, electronic groups outperformed nonelectronic groups ($F_{1,48} = 13.77$, $p < .01$), thus replicating the findings of Gallupe and colleagues (1991). We found that the larger groups—4 and 6 people—produced more ideas than the smaller groups ($F_{2,48} = 18.89$, $p < .01$). An interaction effect qualifies both findings. When the larger groups used the electronic technology, the increase in productivity was more pronounced than it was when the larger groups used the nonelectronic technology, producing a significant interaction effect for technology by group size ($F_{2,48} = 7.81$, $p < .01$).

Post hoc Tukey tests ($\alpha = .05$) showed that 4- and 6-member electronic brainstorming groups generated more ideas than equivalently sized nonelectronic brainstorming groups but showed no difference for 2-member groups. Although the larger nonelectronic brainstorming groups appeared to generate more ideas than the smaller nonelectronic groups ($\overline{x}$'s = 26.20, 31.80, and 35.90), post hoc Tukey tests showed no significant differences between the three group sizes. Tukey tests did, however, reveal that 4- and 6-member electronic brainstorming groups generated more ideas ($\overline{x}$ = 42.20 and 69.80) than 2-member electronic brainstorming groups ($\overline{x}$ = 24.80).

For the quality of ideas, the same pattern emerged (see Tables 1 and 2), in part because the number of unique ideas generated affected the two quality measures. We found that the electronic groups had a higher overall quality score and generated more high-quality ideas than the nonelectronic groups ($F_{2,48} = 29.35$, $p < .01$, and $F_{2,48} = 20.28$, $p < .01$). The larger groups had higher overall quality scores and more high-quality ideas than the smaller groups ($F_{2,48} = 33.67$, $p < .01$, and $F_{2,48} = 27.84$, $p < .01$). These main effects are again qualified by a significant interaction effect for both the quality score and number of high-quality ideas ($F_{2,48} = 9.32$, $p < .01$, and $F_{2,48} = 6.80$, $p < .01$). Post hoc Tukey tests ($\alpha = .05$) indicated that the larger electronic groups had higher quality scores and more high-quality ideas than larger nonelectronic groups, but this pattern was not true for the 2-member groups. Therefore, results only partially supported Hypothesis 1 because 2-member electronic groups did not outperform 2-member nonelectronic groups. Hypothesis 2 was fully supported since the productivity of electronic brainstorming groups increased with group size, but that of nonelectronic brainstorming groups did not.

Tables 1 and 2 also present the means, standard deviations, and results of statistical tests of subjects' perceptions of production blocking, evaluation apprehension, and satisfaction with the process. All items in the three scales were assessed on seven-point, verbally anchored formats (1 = strongly agree, 7 = strongly disagree). We measured production blocking using three items: whether subjects expressed ideas immediately after they

TABLE 1
Means and Standard Deviations, Experiment 1

Dependent Variables	Group Size 2: Electronic Brainstorming	Group Size 2: Nonelectronic Brainstorming	Group Size 4: Electronic Brainstorming	Group Size 4: Nonelectronic Brainstorming	Group Size 6: Electronic Brainstorming	Group Size 6: Nonelectronic Brainstorming
Number of nonredundant ideas[a]						
Means	24.80	26.20	42.20	31.80	69.80	35.90
s.d.	8.22	9.68	11.77	11.87	19.10	10.11
Overall quality score[a]						
Means	70.95	67.65	125.30	81.35	205.90	109.20
s.d.	18.84	33.14	35.15	26.52	51.58	31.74
Number of high-quality ideas[a]						
Means	10.00	10.10	17.30	11.10	28.10	16.10
s.d.	3.33	5.68	3.71	3.66	7.84	5.42
Production blocking[b,c]						
Means	2.13	2.03	2.23	2.74	2.31	3.27
s.d.	0.95	1.24	1.03	1.19	1.05	1.34
Evaluation apprehension[b,c]						
Means	2.42	2.32	2.25	2.87	2.04	3.24
s.d.	1.21	1.00	0.90	1.10	0.87	1.54
Satisfaction[b,c]						
Means	5.05	5.72	5.36	5.22	5.38	4.81
s.d.	1.29	0.83	1.30	0.88	1.15	1.35

[a] Data are for 30 groups, two observations per group.
[b] Data are for 120 subjects, two observations per individual.
[c] The higher the value, the stronger the perception or attitude.

TABLE 2
Results of ANOVA, Experiment 1

Dependent Variables	Technology	Group Size	Technology by Group Size	Mean Square Error
Number of nonredundant ideas	13.77**	18.89**	7.81**	91.08
Overall quality score	29.35**	33.67**	9.32**	1,176.52
Number of high-quality ideas	20.28**	27.84**	6.80**	26.92
Production blocking	7.91**	6.41**	3.01*	1.25
Evaluation apprehension	27.33**	0.82	5.06**	1.33
Satisfaction	0.85	1.26	4.58**	1.40

* $p < .05$
** $p < .01$

thought of them, whether they expressed all ideas that occurred to them, and whether they had to wait to express ideas. We report the average for the three items (Cronbach's α = .78). Significant main effects emerged for both technology and group size ($F_{1,235}$ = 7.91, $p < .01$, and $F_{1,235}$ = 6.41, $p < .01$). As expected, electronic group members perceived less production blocking than nonelectronic group members. Individuals in larger groups felt there was more production blocking than did individuals in smaller groups. A significant interaction effect qualifies these results ($F_{1,235}$ = 3.01, $p < .05$). The members of the three sizes of electronic brainstorming group reported little difference in perceived production blocking. In contrast, nonelectronic brainstorming groups reported increasing production blocking as group size increased.

Subjects' perceptions of evaluation apprehension were measured by three items: whether they felt at ease, whether they were apprehensive, and whether they felt comfortable. We report the average for the three items (Cronbach's α = .83). A significant main effect emerged for technology ($F_{1,235}$ = 27.33, $p < .01$). As expected, members of electronic groups felt less apprehensive than nonelectronic groups. A significant technology-by-group-size interaction qualifies this finding ($F_{1,235}$ = 5.06, $p < .01$). Post hoc Tukey tests (α = .05) found that members of electronic brainstorming groups of the three sizes had similar perceptions, although members of 2-person groups may have been slightly more apprehensive. The perceptions of evaluation apprehension in the 2-member nonelectronic brainstorming groups closely matched those in the 2-member electronic brainstorming groups, but the evaluation apprehension of nonelectronic groups increased with group size, so that 6-member nonelectronic brainstorming groups reported more evaluation apprehension than 6-member electronic brainstorming groups.

The perception of satisfaction was measured by two items: Were you satisfied with the process used? Would you advocate this process to generate ideas? We report the average for the two items (Cronbach's α = .79).

We found a significant interaction effect ($F_{1,235} = 4.58$, $p < .01$). Post hoc Tukey tests ($\alpha = .05$) indicated that again, perceptions were similar across the three group sizes for the electronic brainstorming groups, although individuals in the 2-member groups may have been slightly less satisfied. Perceptions of satisfaction in the 2-member nonelectronic brainstorming groups matched those in the 2-member electronic brainstorming groups, but satisfaction decreased as groups became larger; the 6-member nonelectronic brainstorming groups reported less satisfaction than did the 6-member electronic brainstorming groups.

EXPERIMENT 2

Methods

The purpose of experiment 2 was to provide an additional test of the hypotheses in a different environment using a different subject pool and a different manipulation of group size. The groups studied had 6 and 12 members. We chose the smaller size to match the largest size in experiment 1 and chose the larger size because Osborn (1954) advocated verbal brainstorming groups of up to 12 members, and groups of this size have used electronic brainstorming in field studies (cf. Nunamaker, Applegate, & Konsynski, 1988).

Subjects. One hundred forty-four undergraduate students (92 men and 52 women) enrolled in a production-operations management course at the University of Arizona participated for partial course credit. Their mean age was 23.5 years. There were eight groups of each of the two sizes. Twenty-eight percent of the subjects had prior experience using electronic brainstorming. We randomly assigned all subjects to groups and randomly assigned groups to treatments.

Task. The questions were the same as in experiment 1 but were modified to fit local conditions. Subjects generated ideas on "How can tourism be improved in Tucson?" and "How can campus security be improved at the University of Arizona?" In addition, the same two practice questions were used.

Treatments and procedures. Groups had either 6 or 12 members. All groups brainstormed using the same technologies used in experiment 1 under the same, fully balanced, repeated measures design used in experiment 1. Procedures were also the same for the two experiments.

Dependent variables. The dependent variables were the same as those in experiment 1, and the same experienced, treatment- and hypotheses-blind coders who coded the ideas for experiment 1 coded the data for the second experiment.

Results

All variables were analyzed using the same procedures as were used in experiment 1. Group size was a two-level between-groups factor, and technology was a two-level within-group factor. A preliminary analysis of the number of ideas generated for the two problems indicated no significant main effects for the problems or their sequence. As in experiment 1, a two-factor (technology by group size) ANOVA was conducted on each question of the presession questionnaire to determine whether there had been any significant differences between the groups before the session began. No pre-session differences emerged.

An ANOVA of the number of nonredundant ideas generated again showed all three effects were statistically significant (see Tables 3 and 4). Electronic groups again outperformed nonelectronic groups ($F_{1,28} = 42.02$, $p < .01$), thus replicating the results from experiment 1, although this finding is again qualified by the technology-by-group-size interaction effect ($F_{1,28} = 22.27$, $p < .01$). The larger groups again produced more ideas than the smaller groups ($F_{1,28} = 20.88$, $p < .01$). This pattern was particularly true for

TABLE 3
Means and Standard Deviations, Experiment 2

	Group Size			
	6		12	
Dependent Variables	**Electronic Brainstorming**	**Nonelectronic Brainstorming**	**Electronic Brainstorming**	**Nonelectronic Brainstorming**
Number of nonredundant ideas[a]				
Means	39.10	30.20	85.90	29.50
s.d.	10.32	12.04	23.43	3.62
Overall quality score[a]				
Means	146.00	99.10	340.00	111.00
s.d.	36.20	38.70	102.00	28.70
Number of high-quality ideas[a]				
Means	25.00	17.12	64.62	20.00
s.d.	7.56	7.81	14.94	4.60
Production blocking[b,c]				
Means	2.69	3.11	2.34	3.66
s.d.	1.26	1.26	1.20	1.37
Evaluation apprehension[b,c]				
Means	2.33	3.13	2.01	3.78
s.d.	0.95	1.23	0.96	1.38
Satisfaction[b,c]				
Means	5.07	4.73	5.64	4.35
s.d.	1.41	1.30	1.12	1.26

[a] Data are for 16 groups, two observations per group.
[b] Data are for 144 subjects, two observations per individual.
[c] The higher the value, the stronger the perception or attitude.

TABLE 4
Results of ANOVA, Experiment 2

Dependent Variables	Technology	Group Size	Technology by Group Size	Mean Square Error
Number of nonredundant ideas	42.02**	20.88**	22.27**	202.62
Overall quality score	43.58**	24.52**	19.19**	3,488.21
Number of high-quality ideas	70.42**	32.72**	23.68**	90.60
Production blocking	29.42**	0.35	8.11**	3.18
Evaluation apprehension	78.18**	1.29	10.92**	1.96
Satisfaction	27.10**	0.37	9.01**	1.59

* $p < .05$
** $p < .01$

the electronic groups, as indicated by the significant interaction effect: 12-person electronic brainstorming groups generated more ideas than 6-person electronic brainstorming groups, but there was no difference between 6- and 12-member nonelectronic brainstorming groups.

The same procedures used in experiment 1 were used to assess idea quality. The pattern for the overall quality score and the number of high-quality ideas was the same as in experiment 1. All three effects were statistically significant for both measures. The electronic groups generated more high-quality ideas than the nonelectronic groups ($F_{1,28} = 70.42$, $p < .01$), and the larger groups produced more high-quality ideas than the smaller groups ($F_{1,28} = 32.72$, $p < .01$). As in our analysis of the number of nonredundant ideas generated, follow-up Tukey tests for idea quality indicated that the interaction effect ($F_{1,28} = 23.68$, $p < .01$) was due to the 12-person electronic brainstorming groups generating more high-quality ideas than the 6-person electronic brainstorming groups, but no difference emerged for large and small nonelectronic brainstorming groups. Thus, findings supported both Hypotheses 1 and 2.

Tables 3 and 4 present means, standard deviations, and results of statistical tests of subjects' perceptions. The alphas for the three perceptual measures were similar to the values in experiment 1 (.73 for production blocking, .84 for evaluation apprehension, and .78 for satisfaction). All three perceptual measures produced technology and technology-by-group-size effects. As in experiment 1, members of electronic brainstorming groups perceived less production blocking than members of nonelectronic groups ($F_{1,285} = 29.42$, $p < .01$). Post hoc Tukey tests indicated that the interaction effect was the result of the members of both sizes of electronic group reporting little difference in production blocking. In contrast, the 12-person nonelectronic brainstorming groups reported more production blocking than the 6-member groups ($F_{1,285} = 8.11$, $p < .01$).

For evaluation apprehension, members of both sizes of electronic brainstorming group had similar perceptions. In contrast, perceptions of evaluation apprehension in the nonelectronic brainstorming groups increased with group size: members of the 12-person nonelectronic brainstorming groups reported more evaluation apprehension than members of the 12-person electronic brainstorming groups. As a result, we found significant interaction and technology effects ($F_{1,285} = 10.92, p < .01$, and $F_{1,285} = 78.18, p < .01$).

The perceptions of satisfaction were again similar to those in experiment 1, but they were more pronounced. The members of the electronic groups were more satisfied than those of the nonelectronic groups ($F_{1,285} = 27.10, p < .01$), indicating a main effect for technology. A technology-by-group-size interaction qualified the main effect ($F_{1,285} = 9.01, p < .01$). Perceptions of satisfaction increased with group size for electronic groups but decreased with group size for nonelectronic groups.

DISCUSSION

The results of the two experiments are highly consistent and can be quickly summarized. Technology did not affect productivity when there were 2 people in a group but did have a significant effect on productivity when there were 4, 6, or 12 people. Our 4-person groups replicated the earlier finding that the productivity of electronic brainstorming groups is higher than that of nonelectronic brainstorming groups (Gallupe et al., 1991). The growing superiority of the electronic brainstorming groups of 6 and 12 members extended those results. In the electronic groups, performance increased substantially with group size. In contrast, performance in the nonelectronic brainstorming groups did not increase as group size increased.

The results demonstrate both the limits and strengths of electronic brainstorming. Technology did not make a difference when there was no anonymity and only limited production blocking (the 2-person groups). Thus, the benefits of electronic brainstorming appear limited at the lowest bound of group size. The advantages of electronic brainstorming became pronounced as anonymity increased in electronic brainstorming groups and production blocking increased in nonelectronic brainstorming groups. Examining the per person productivity in the variously sized groups across the two technologies sharply illustrates that pattern. In experiment 1, per person output in the nonelectronic brainstorming groups fell steadily as group size increased ($\overline{x}$'s = 13.10, 7.95, and 5.98, respectively). But for the electronic groups means were 12.40, 10.55, and 11.64. Thus, per person productivity fell as nonelectronic brainstorming groups became larger but remained steady for electronic brainstorming groups; this produced a significant technology-by-group-size interaction on average number of ideas per person ($F_{2,27} = 11.54, p < .01$).

In experiment 2, the average per person output of ideas in the nonelectronic brainstorming groups again fell with group size; there were 5.0 ideas and 2.5 ideas per person respectively in the 6- and 12-person groups. In contrast, no change occurred in the electronic brainstorming groups (6.0 and

7.2 ideas).[2] Increasing group size appeared to hamper idea generation in the traditional brainstorming groups but did not do so in the electronic brainstorming groups; the technology-by-group-size effect for average number of ideas per person was significant ($F_{1,14} = 12.98$, $p < .01$).

We attribute these results to differences in production blocking and evaluation apprehension. Production blocking should increase as group size increases in nonelectronic brainstorming groups because many group members are attempting to state their ideas but cannot because someone else is speaking. In contrast, all members of electronic brainstorming groups can work simultaneously. Thus, production blocking should not differ with the size of electronic groups. The postsession measure of production blocking supported this explanation. In both studies, we found that electronic brainstorming groups reported less production blocking than nonelectronic brainstorming groups and that production blocking was most pronounced for the larger nonelectronic brainstorming groups. We conclude that one reason for the differences in the number of ideas generated across technology and group size is that production blocking remained at a relatively constant, low level in the electronic brainstorming groups but increased for nonelectronic brainstorming groups as they became larger.

Results are also attributable to differences in evaluation apprehension between the two technologies. Evaluation apprehension in nonelectronic brainstorming groups may increase as group size increases because there are more people available to be critical of an idea. In contrast, except in 2-member groups, ideas entered by members of electronic brainstorming groups are anonymous, and evaluation apprehension should not increase with group size. Our postsession data supported this interpretation in both experiments. Members of the electronic brainstorming groups reported less apprehension than did members of the nonelectronic brainstorming groups. Perceptions of evaluation apprehension remained constant across group size for members of electronic brainstorming groups but increased with group size for nonelectronic brainstorming groups. This pattern is consistent with the view that apprehension will increase with the number of potentially critical members in verbal groups. We conclude that the technology's effect on production blocking and evaluation apprehension is the most likely explanation for the observed effects on the productivity of larger and smaller electronic brainstorming and nonelectronic brainstorming groups.

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[2] The difference in the number of unique ideas produced was an unanticipated difference between the two experiments. Although the same coders assessed the ideas from both experiments, the 6-person groups at Queen's produced many more ideas than the Arizona groups. One explanation is that the demographic compositions of the groups were somewhat different. The average age of the Queen's groups' members was lower, and the groups contained higher percentages of women and individuals who had no experience with the electronic brainstorming technique. Another explanation is that the tasks were more relevant and motivating for one group than for the other. For example, promoting tourism in Kingston, Ontario, may be more of a concern than it is in Tucson, Arizona.

In addition, the members of the electronic brainstorming groups were more satisfied than the members of the nonelectronic brainstorming groups. Further, although satisfaction increased with group size for electronic groups, it decreased for the nonelectronic groups. Thus, the technology not only eliminated the per person productivity decline that is normally found as groups grow in size, but also increased the satisfaction of group members.

One other possible explanation should be noted: novelty. If subjects found the electronic brainstorming technology more engaging because it was novel, they may have worked harder and produced more ideas. The design of the experiments does not provide a strong test of this account. It does, however, provide a weak test. In experiment 1, none of the subjects had previous experience with electronic brainstorming, whereas 28 percent of the subjects in experiment 2 had prior experience. That level of diminished novelty in experiment 2 was not sufficient to eliminate the effects of the technology. In addition, novelty cannot easily account for the significant interaction of technology and group size found in both experiments. If novelty were a factor, differences between experienced and inexperienced subjects might show up in the postsession data, but an analysis of those data comparing experienced and inexperienced subjects showed no differences for production blocking, evaluation apprehension, and satisfaction.

Finally, our results for the quality of ideas are similar to those for the number of unique ideas generated. The groups that generated more unique ideas (the larger electronic brainstorming groups) also generated more high-quality ideas. It is reassuring to note that quality did not suffer when quantity increased.

IMPLICATIONS

The main finding of this study was that the productivity of electronic brainstorming groups increased with size, but the productivity of traditional brainstorming groups did not so increase. These results have several implications for researchers and practitioners.

Implications for Research

The benefits of parallel entry and anonymity that electronic brainstorming provides likely contributed to the improved performance and satisfaction of the electronic brainstorming groups. It is unclear which of these benefits is the more important in improving performance and satisfaction. An immediate task for researchers is to tease out the comparative effects of production blocking and anonymity, while keeping in mind the difficulties of conducting fair comparisons (Cooper & Richardson, 1986).

A second implication for researchers is that the benefits of electronic brainstorming need to be assessed over a wider range of group sizes. It seems unlikely that the increase in the per person productivity in electronic brainstorming groups will remain constant over an infinite increase in size, in part because people would run out of ideas, and in part because the temptation to free ride would increase as group size increased (Albanese & Van Fleet, 1985). Thus, a second task for research is to extend the size of electronic brainstorming groups and assess the extension's impact on productivity.

A third implication is that electronic brainstorming needs to be studied in conjunction with other group tasks. Idea generation is only one type of task groups in organizations perform. We found that electronic technology can enhance idea generation by groups of varying size. One important question is whether the new electronic tools can aid in the performance of other group tasks. Brainstorming has pooled interdependence (Thompson, 1967): members do not depend on other members to perform tasks before they can perform theirs. Electronic groups may not perform as well on tasks that have sequential interdependence because keyboarding is slower than talking and lacks some of the richness of speech (Daft & Lengel, 1984). Electronic brainstorming may turn out to be ideal for generating ideas because of the pooled interdependence involved but may not be so helpful when sequential, subtle communication is required.

Implications for Practice

For practitioners, an implication of these results is that increasing group size, at least in the range we assessed, should not be considered a constraint on the effectiveness of idea generation groups. Electronic technology can support the brainstorming activities of groups of 12 members and possibly more. Our data indicate that even in 12-member groups, individuals feel satisfied with the electronic brainstorming process and feel they can get their ideas expressed. At the minimal size of 2, the choice of technology depends on grounds other than productivity.

Another implication for practitioners is that the anonymity electronic brainstorming provides may reduce the inhibitory effects of status differences. Status differences are likely to reduce the willingness of organization members to express their views, particularly if those views raise questions of loyalty and team play (cf. Jackall, 1988). With electronic brainstorming, lower-status members of a management group may be willing to air their ideas without feeling as apprehensive as they would in verbal brainstorming about whether higher-status members will react negatively to those ideas. The anonymity electronic brainstorming provides may also make it easier for group members to play devil's advocate. Electronic brainstorming will not eliminate all the risk of stating ideas, but it may reduce it, particularly in larger, hierarchical groups.

Electronic brainstorming also enables group members in dispersed locations to generate ideas interactively. In this mode, electronic brainstorming is a sophisticated form of computer conferencing wherein group members' ideas are automatically sent to each other's screens during the idea generation session. This process may be particularly helpful when people's schedules differ markedly because of time zones and work loads. It may offer an attractive alternative to conference calls that require everyone to be available to interact at the same time.

Finally, the simultaneity of input in electronic brainstorming also prevents one individual from dominating the idea generation process. Inputs tend to be evenly distributed over group members, which helps increase not only the number of ideas generated but also people's satisfaction with the process.

This study raises additional questions about the adoption and use of this technology by organizational groups. For example, how can groups using electronic brainstorming integrate their results into subsequent activities, such as idea organization, multicriteria decision making, and stakeholder benefits' analysis, that may or may not be supported by other electronic technologies? Will group performance and satisfaction with electronic brainstorming technologies change over time, as groups and organizations gain experience with them? Can the presence of this technology influence the composition of groups using it in such a way that large groups encompassing a wide range of organizational stakeholders can resolve key issues? Further research using both experimental laboratory studies and field studies is needed to determine the effects of the use of new electronic group technologies.

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