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Understanding the Group Size Effect in Electronic Brainstorming

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Abstract

A number of studies on electronic brainstorming have found that large electronic groups can facilitate the number of ideas generated relative to control groups of similar numbers of solitary performers (nominal groups). Thus far there is no clear evidence for the basis of this facilitative effect. The most likely explanation is that group members benefit from exposure to the wide range of ideas in large groups. Since most electronic brainstorming studies appear to divide the presented ideas into subfolders to avoid overloading participants with too many ideas, this practice may be important for demonstration of a benefit of exposure to a large number of ideas. The present study was designed to assess the role of number of ideas and number of folders on individual idea generation and to eliminate some alternative interpretations for the group size effect. Participants performed an idea generation task on computers while being exposed to either no ideas, 28 ideas, or 112 ideas. The 28 and 112 ideas were presented in either one, four, or eight folders. The results indicated that only the number of ideas factor was important for facilitating idea generation.

Keywords

brainstorming, computer-mediated communication, creativity

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The generation of new ideas is important for any enterprise as it attempts to innovate. Although there are many ways to generate good ideas, one of the more popular techniques involves brainstorming (Osborn, 1957). The classic brainstorming process involves generating ideas by focusing on generating a large quantity of ideas while deferring evaluation until a later session. The assumption is that by generating a large quantity of ideas, there is an increased probability of producing good solutions. This is in fact true (cf., Paulus, Kohn, & Arditti, 2011), and we have discovered much about the brainstorming process and how to enhance brainstorming (Nijstad & Stroebe, 2006; Paulus & Coskun, 2012). However, it has been more difficult to demonstrate that interaction in groups generates a synergistic benefit. That is as follows: Does group interaction enhance the number of ideas and their quality relative to the pooled production of a similar number of individuals who generate ideas without sharing them (nominal groups)?

The demonstration of such creative synergy requires that group members are highly motivated and effectively process shared ideas (Baruah & Paulus, 2009; De Dreu, Nijstad, Bechtoldt, & Baas, 2011; Kohn, Paulus, & Choi, 2011; Paulus & Brown, 2003). Evidence of collaborative synergy in idea-generating groups has been found primarily with paradigms that involve exchanging ideas by writing or computer systems (Dennis & Williams, 2003; Paulus & Yang, 2000). The focus of this article will be on evaluating the basis for the synergistic effect of collaborative idea generation using computer systems or electronic brainstorming (EBS). The EBS literature has demonstrated that as group size increases, the benefit of exchanging ideas also increases relative to ideas generated by nominal groups (Derosa, Smith, & Hantula, 2007). However, the basis for this synergistic benefit is not clear, and the purpose of the present study is to shed some light on this issue.

Electronic Brainstorming in Groups

Although it is generally presumed that brainstorming with others will enhance the number and quality of the ideas generated, controlled studies that compare interactive brainstorming with nominal groups have shown that verbal brainstorming in groups actually hinders the number of ideas generated (Diehl & Stroebe, 1987; Mullen, Johnson, & Salas, 1991). This has been attributed to a range of factors such as reduced motivation in groups (i.e., social loafing, Karau & Williams, 1993), concern with evaluation of ideas in groups (Camacho & Paulus, 1995), group members matching their performance to that of the low performers in the group (Paulus & Dzindolet, 1993), or the fact that only one idea can be expressed at one time in the group (Diehl & Stroebe, 1987). From this perspective it is not surprising that the

productivity deficit between real groups and nominal groups increases with group size (Bouchard & Hare, 1970).

With the development of interactive computer systems, sharing ideas by means of computers has become a common approach (Dzindolet, Paulus, & Glazer, 2012). Systematic studies of this type of idea sharing or electronic brainstorming have indeed found that this approach can facilitate collaborative ideation (Gallupe, Bastianutti, & Cooper, 1991; Gallupe et al., 1992). It has been found that verbal brainstorming groups are typically outperformed by similar size EBS groups in terms of number of ideas, number of high quality ideas, and average quality of ideas (Dennis & Williams, 2003; Derosa et al., 2007). The positive effect of the electronic paradigm has been attributed primarily to the reduction in production blocking, since group members can share ideas as they occur (Gallupe et al., 1991). The benefits of EBS can also be related to feelings of anonymity since ideas can be shared without attribution to a specific individual. This can reduce the degree of evaluation apprehension and thus increase the number of ideas generated. However, reviews of the literature indicate no clear effect of anonymity in EBS (Dennis & Williams, 2005; Derosa et al., 2007). Thus reduced production blocking in EBS appears to be the main factor responsible for its performance benefits.

The benefit of EBS on ideation generation appears to depend on the size of the group and the manner in which the idea sharing is structured. The productivity deficit for interacting groups is also observed in EBS when comparing interactive and nominal groups of small group sizes (eight or less). For groups larger than eight there appears to be a benefit of sharing ideas in groups (e.g., synergy, Larson, 2009) as they generate more ideas (but not more original ideas) than nominal groups (Dennis & Williams, 2005; Derosa et al., 2007). It should be noted that these meta-analytic reviews included studies that did not vary group size (used only one group size). Furthermore, the key comparison in these reviews was between a particular size EBS group and a comparable size nominal group. Another problem in evaluating the group size effect is that many studies report the total number of ideas generated in the groups. In general, larger groups are going to generate more ideas. However, if one examines the number of ideas per person in all of the studies that actually varied group size in EBS, the picture is less clear. In only three of the 10 experiments that used this measure did the number of ideas per person increase with larger groups (Dennis & Valacich, 1993; Gallupe, et al., 1992; Valacich, Dennis, & Connolly, 1994). In the other experiments there was either no trend or a trend to more ideas per person in smaller groups. It is possible that variations in the EBS procedure may have been responsible for these differences. Even though the group size effect may not be as robust as implied by a number of scholars, this effect is seen as an important

demonstration of creative synergy in groups. Thus, it is important to determine the basis for this synergistic effect.

A number of factors have been highlighted as being important in understanding the group size effect in EBS (cf., Dennis & Williams, 2003; Dzindolet et al., 2012; Paulus & Brown, 2003). The most obvious is the impact of exposure on increased numbers of ideas. As group members are exposed to more ideas this should lead to increased stimulation of semantic networks and additional ideas (Brown & Paulus, 2002; Nijstad & Stroebe, 2006; Paulus & Brown, 2007). Exposure to ideas from others may also have motivational effects since individuals may use the number of ideas generated by others as a reference point for their own performance—a social comparison effect (Dugosh & Paulus, 2005; Paulus & Dzindolet, 1993). When group members are present in the same room as they are generating ideas, there may also be a social facilitation effect. That is, the presence of other group members can increase arousal and enhance performance on an idea-generation task (Geen, 1980; Zajonc, 1980). However, exposure to others' ideas can also have a variety of negative effects. Reading ideas of others can limit the time one has to generate one's own ideas, or reading these ideas as they are presented may interrupt the individual flow of ideas within specific categories (Baruah & Paulus, 2011). This interference effect should increase with increasing numbers of ideas. Exposure to ideas from others may also increase idea uniformity since these ideas may prime similar ideas. Exposure to a large number of ideas may result in cognitive overload and a tendency to ignore the presented ideas. Since increased group size is related to enhanced performance in EBS, obviously the positive effects of idea exposure must outweigh the negative ones. However, there is lack of clarity as to the relative importance of the positive mechanisms. In this study we will evaluate the role of the cognitive stimulation factor while controlling for the potential effect of social facilitation and social comparison. We will discuss the primary issues of interest for this study in more detail and suggest several hypotheses.

Hypotheses

If exposure to ideas from others is both distracting and stimulating, why do we observe a positive effect of group size on ideation with EBS? In small groups the distracting effect of monitoring ideas from others may outweigh the advantage. The time spent reading ideas limits the number of ideas generated. Thus, small EBS groups may perform more poorly than similar size nominal groups. However, with large groups the large number of ideas shared may increase exposure to unique ideas, which in turn facilitate generation of additional ideas (Dennis & Williams, 2005). In large groups, participants

discover that many of the ideas they might have generated have already been generated by others. Such discoveries may increase the pressure or motivation to come up with more unique ideas. However, other studies have found that unique ideas may not have any special stimulation value (Connolly, Routhieaux, & Schneider, 1993; Dugosh & Paulus, 2005). Furthermore, when group members in a small EBS group are instructed that they should remember the exposed ideas, these groups outperform nominal groups (Dugosh & Paulus, 2005), and other studies have shown that simply exposing individual performers to ideas from others enhances the generation of ideas (Dugosh, Paulus, Roland, & Yang, 2000; Nijstad, Stroebe, & Lodewijkx, 2002). We interpret the various findings as indicating that the group size effect in EBS may primarily reflect the stimulating effect of increasing numbers of ideas. Thus we hypothesize that exposure to a large number of ideas will lead to stimulation of more ideas and more categories of ideas than exposure to a small number of ideas.

EBS is typically done in one room with a number of stations. In all but one of the studies of group size covered in the Derosa et al. (2007) review, the participants were present in the same room. It is possible that in large groups the presence of a large number of other participants will have a motivational effect. The presence of a large number of other participants may increase the level of arousal and thus enhance the number of ideas generated (Zajonc, 1980). Alternatively, increasing the number of participants may increase feelings of competition (Hüffmeier & Hertel, 2011; Paulus, Dugosh, Dzindolet, Coskun, & Putman, 2002). Thus the effect of group size in EBS may be due to motivational factors rather than cognitive stimulation. We controlled for the social facilitation factor by having individuals perform in separate rooms while they were exposed to ideas generated previously by other students. Since each participant was performing individually, he or she did not have access to the performance of others, which meant there was also no opportunity for motivational effects of social comparison.

Exposure to others' ideas can also lead to uniformity as group members may focus on a limited set of idea domains or categories (Kohn & Smith, 2011; Ziegler, Diehl, & Zijlstra, 2000). Although it has been suggested that increasing the number of ideas should increase the chance of exposure to unique ideas, it is also possible that such increased exposure will increase the reliance on the exposed ideas as a basis for one's own ideas. Exposure to a high number of ideas may increase the extent to which participants conform their ideas to the presented ideas. We hypothesize that the conformity rate will be higher in the conditions where participants receive a large number of ideas.

An important factor in the effect of ideas presented electronically is the extent to which participants pay attention to these ideas (Dugosh et al., 2000; Dugosh & Paulus, 2005). Electronic brainstorming systems do not require one to attend to the ideas as they are presented—they are simply available for perusal if the participant is motivated or interested, thus allowing a participant to continue developing his or her current ideas without being interrupted. Of course, as the number of ideas presented increase, there may be an experience of cognitive overload (Dennis & Valacich, 1993; Grise & Gallupe, 2000; Nagasundaram & Dennis, 1993; Santanen, Briggs, & de Vreede, 2004; Valacich et al., 1994). That is, participants may become overwhelmed with the high rate of ideas and begin *tuning out* or completely ignoring the shared ideas.

Most of the studies with large groups used Groupsystems by Ventana, which uses a virtual folder system. This system aids in the pace of presentation of ideas in EBS by dividing them among folders. As ideas are generated in a group, they are assigned to the different folders. When a participant submits an idea, he or she is presented with the next folder, which contains the ideas that have been assigned to that folder. As group size increases, the number of folders required also typically increases (R.O. Briggs, personal communication, October 21, 2009; Dennis et al., 2005; Dennis & Williams, 2003; Pinsonneault, Barki, & Hoppen 1999). However, only a few of the studies reported this detail in their procedure section, so it is not possible to determine by reading the papers whether the extent to which larger groups lead to more ideas per person is related to the use of folders. Several studies have shown that *chunking* ideas into smaller sets or presenting them in different windows (Dennis, 1996; Dennis et al., 1997; Dennis, Valacich, Connolly, & Wynne, 1996; Nagasundaram & Dennis, 1993) enhances the number of ideas generated. Thus, it is possible that increasing the number of folders while increasing group size is critical in enabling large groups to demonstrate enhancement of idea generation relative to nominal groups. It is hypothesized that the benefit of a high number of ideas will be most evident when these ideas are presented in multiple folders. However, in the low number of ideas condition, there is expected to be little benefit of number of folders since participants are not overloaded with ideas.

Study Overview

The present study simulated EBS by presenting ideas to participants while they were generating ideas as individuals. The simulation allowed us to test for the cognitive impact of exposure to variation in number of ideas and of having these ideas presented in folders without the confounding effects of

social comparison and social facilitation. Since participants were in individual rooms and did not see each others' responses, there could be no social comparison or social facilitation effect. We presented participants with either 28 or 112 ideas. Since we have found that a rate of one idea per minute per person is a typical of EBS, the 112-ideas condition provides an idea exposure level similar to that in a group of nine. The 28-ideas condition is similar to the exposure in a group of three. The ideas in these two conditions were displayed in one, four, or eight lists or folders. The advantage of using predetermined ideas in the simulation design is that one can control the degree of uniqueness and utility of the presented ideas. Dennis et al. (2005) also varied the actual number of ideas presented—either none, 28 or 56. Presenting these ideas actually hindered performance for the first two sessions of three different brainstorming tasks, but showed a slight benefit in the third session. They did not find a difference between the 28 and 56 idea conditions, possibly because the range of ideas was too limited.

We also examined the effect of time on task for some of the dependent measures by dividing the brainstorming session into two halves. Past studies that have examined trends over time have found that the number of ideas generated decline over time. However, it is often suggested that more original ideas will occur later in the session, since the more easily accessible or common ideas will tend to be tapped early in the memory search process (Brown & Paulus, 2002). Thus far there has been little evidence for this prediction (Kohn & Smith, 2011). It is also possible that the effects of our manipulations will interact with the time of the session (early vs. late). However, we did not have any a priori hypotheses about this possible interactive role of the time variable. The main dependent variables of interest were number of ideas generated (quantity), the number of categories in which ideas were generated (variety), the average quality of ideas generated (originality & utility), and the degree of idea conformity (similarity of generated ideas to presented ideas). Quantity and variety are typically highly correlated but quantity and average quality are not usually correlated (cf., Baruah & Paulus, 2011). Group size effects in EBS have been related to an increase in number of ideas generated but not in average quality.

In sum, we tested the following hypotheses:

Hypothesis 1: Exposure to a greater number of ideas will increase the number of ideas and the number of categories of ideas generated during EBS. This should be reflected in main effects of the number of idea manipulation. Average quality will not be affected by the number manipulation.

Hypothesis 2: Ideas generated by participants in the 112-ideas condition will be more influenced by the presented ideas (as reflected in a measure of idea conformity) than those in the 28-idea condition.

Hypothesis 3: Increasing the number of folders will facilitate performance of participants in the 112-ideas condition but not those in the 28-ideas condition. Thus we predict an interaction of number of ideas and number of folders for the quantity and variety measures, with the best performance in the 112-ideas and eight folders condition.

Hypothesis 4: In the second half of the brainstorming session participants will generate fewer ideas but also more novel ideas. More common and potentially useful ideas will be generated in the first half.

Method

Participants

The participants were undergraduate students enrolled in introductory psychology courses. A total of 162 students participated in the study. Data from two participants were deleted from the study due to experimenter error. Of the participants used in this study, 85 were female and 77 were male with an average age of 21. Up to three students could participate in any one session. Each participant was randomly assigned to one of the seven conditions used in this study.

Materials

Participants were asked to generate ideas on how to improve their university. The control condition, which did not provide the participants with ideas from the computer, used AOL Instant Messenger as the brainstorming interface. For the experimental conditions, a computer program was created for the purpose of presenting ideas from the computer and receiving ideas from the participants. These ideas originated from a bank of ideas brainstormed by participants from an earlier study that used the same brainstorming problem (Paulus et al., 2011). “More organized school bus system” and “better housing options” are examples of those ideas. For the 28-ideas condition, one idea appeared from each of 28 categories. For the 112-ideas condition, four ideas appeared from each category. This included all the ideas from the 28-idea condition. The order of the presentation of the ideas was randomized so that ideas from a category would not be presented in a specific order. The first idea appeared 30 seconds into the session and the last idea appeared with 30 seconds left, regardless of condition. For the 28-ideas condition, each idea

was supplied every 30 seconds while in the 112-ideas condition participants received an idea every 7.5 seconds. The presented ideas and the participant's ideas were placed into one, four, or eight folders—creating one, four, or eight lists of ideas. Ideas were added to each folder sequentially, regardless if it was submitted by a participant or by the program.

The ideas provided to participants were coded for originality and utility on a 5-point scale by two independent, trained raters. If the ratings were within 1 point of each other, the ratings were adjusted to match for the reliability analysis; however, for analyses of experimental results the original ratings were used (Diehl & Stroebe, 1991). ICC values for the rated measures were 0.87 for originality and 0.73 for utility. A set of independent *t*-tests compared the two conditions' ideas on the average ratings of the two raters. There was no significant difference between the 28-ideas condition ($M = 2.21$, $SD = 0.82$) and the 112-ideas condition ($M = 2.33$, $SD = 0.86$) on originality. There was also no significant difference between the 28-ideas condition ($M = 2.77$, $SD = 0.83$) and the 112-ideas condition ($M = 2.66$, $SD = 0.87$) on utility. Thus, the ideas presented to participants in the two conditions were comparable in originality and utility.

For the multifolder conditions, participants could view only one folder (the display folder) and all of its contents at a time. The program would only change the display folder after the participants submitted an idea. The display folder rotated in order (e.g., the participant viewed Folder 1 until they submitted an idea; then they could view Folder 2). Therefore, the rotation of the display folder and the rotation of the folder that was next in line to receive an idea were independent from one another. For example, if participants submitted an idea while viewing Folder 1, this idea might be added to Folder 6 because the last idea added to the folders was placed in Folder 5. If the participant chose not to submit any ideas, the program continued to propagate the folder with ideas. For instance, as a participant was viewing Folder 3, the participant would be able to see any new ideas added to Folder 3 but none of the other folders.

Design and Procedure

This study employed a 2 (number of ideas: 28, 112) × 3 (number of folders: 1, 4, 8) design and a control condition in which participants brainstormed without exposure to other ideas. Participants were first given a set of instructions informing them on how to use the EBS program, and they were provided with the brainstorming topic of ways in which to improve their university. The experimenter then escorted each participant to his or her individual room where the brainstorming session would take place. Once

participants read the onscreen instructions, they were prompted to click a start button, which would start a timer and begin the session. They were told that the ideas presented on the screen were generated by past students.

The instructions for the control condition were as follows:

> You are about to participate in an experiment examining idea generation. In a minute you will be given a topic. Your job is to list as many ideas as possible for this topic. These ideas can be as short as a few words. You will submit your ideas by typing the idea into the program and then pressing enter. Do not worry about perfect spelling or grammar. For each idea you submit, it will be sent to the experimenter's computer. However, the experimenter will not communicate with you except for telling you to Start and Stop.

The participants were shown a diagram of how to type the ideas and were given a sheet listing the traditional rules of brainstorming and some extra rules that we have found useful in prior research (Putman & Paulus, 2009). Thus they were told not to judge their ideas, to freewheel, focus on quantity, to stay focused on the task, not to tell stories, and not to explain ideas.

The instructions for the experimental groups were similar except for different procedural details of the EBS program. They were instructed that "to submit an idea, type it into the entry area and hit the enter key on the keyboard after each idea. You will be able to see your ideas and the ideas of previous participants whose ideas are already in the computer. You will be able to view these ideas in the viewing panel." They were also shown a diagram of how to submit their ideas and given the same brainstorming instructions as the control condition. For all conditions, participants were given 15 minutes to brainstorm ideas.

The main dependent measures were quantity, variety, originality, utility, and idea conformity. Each brainstormed idea was classified into one of 28 categories based on past research with this problem (Putman, 2002). Ideas were rated on originality (how unique the idea is compared to ideas suggested by other participants) and utility (how much the idea would have a large, positive impact on the university) on a scale of 1 to 5, with 5 being the greatest originality/utility. Brainstormed ideas in the experimental conditions were coded for conformity. If a participant's idea was judged to be based on a previous computer idea that was visible in the active folder, then the idea was counted as conformity. If a participant's subsequent idea (which would be in a new active window in the four-folder and eight-folder conditions) was also judged to be a continuation of this train-of-thought, then this idea was also counted as an instance of conformity.

Results

Coding

Each brainstormed idea was classified independently by two trained raters into a category. Interrater reliability prior to identification of disagreements, as measured by Cohen's κ, was 0.91. Through discussion, the disagreements were resolved. Ideas were also rated by a trained rater on originality and utility. A second trained rater coded 25% of the ideas to assess interrater reliability. If the raters were within one point of each other they were considered to be in agreement (Diehl & Stroebe, 1991). Interclass correlation (ICC) statistics were 0.91 for originality rating and 0.80 for utility rating.

Each brainstormed idea was also classified independently by two trained raters for conformity to the presented ideas. Interrater reliability prior to identification of disagreements, as measured by Cohen's κ, was 0.88. Through discussion, the disagreements were resolved. To analyze the experimental conditions' ideas temporally, the data were split into two time periods, early (0:00 to 7:29) and late (7:30 to 15:00).

Effect of Increased Exposure to Ideas

We predicted that exposure to a high number of ideas would enhance performance (Hypothesis 1). To analyze how increasing the amount of exposure from the computer affects the quantity and quality of the participants' ideas, a series of one-way ANOVAs compared the control, 28-ideas, and 112-ideas conditions. The means and standard errors for these conditions can be found in Table 1.

There was a main effect for quantity, $F(2, 157) = 3.50$, $MSE = 130.05$, $p = .033$, $\eta^2 = .04$. More ideas were brainstormed in the 112-ideas condition than the other two conditions. Similarly, there was a main effect for variety, $F(2, 157) = 7.75$, $MSE = 15.63$, $p = .001$, $\eta^2 = .09$. More categories were explored in the 112-ideas condition than the other two conditions. A main effect was found for average originality, $F(2, 157) = 3.49$, $MSE = 0.17$, $p = .033$, $\eta^2 = .04$. The control condition yielded more original ideas than the 28-ideas condition. No main effect was found for average utility, $F(2, 157) = 0.36$, $MSE = 0.11$, $p = .695$. These results are consistent with Hypothesis 1 that exposure to a high number of ideas would increase the number of ideas generated and the number of categories used.

Effects of Number of Ideas, Folders and Time

It was predicted that conformity to ideas of others would be higher in the high idea condition (Hypothesis 2). To analyze conformity, a conformity rate was calculated (the number of conformity instances divided by quantity). For

Table 1. Brainstorming Performance as a Function of Condition and Time Period.

	Quantity (*SE*)	Variety (*SE*)	Originality (*SE*)	Utility (*SE*)	Conformity rate (*SE*)
Control	21.33 (*2.26*)	11.13 (*.87*)	3.40 (*.08*)	3.02 (*.06*)	—
Early	13.04 (*1.37*)	8.13 (*.71*)	3.30 (*.10*)	3.11 (*.08*)	—
Late	8.29 (*1.07*)	5.50 (*.67*)	3.71 (*.11*)	2.85 (*.13*)	—
28-ideas	21.96 (*1.14*)	13.28 (*.44*)	3.17 (*.05*)	3.08 (*.04*)	.26 (*.02*)
Early	12.59 (.80)	9.04 (.38)	3.03 (*.06*)	3.12 (*.05*)	.18 (*.02*)
Late	9.36 (.67)	7.06 (.39)	3.42 (*.06*)	3.05 (*.06*)	.33 (*.03*)
112-ideas	26.61 (*1.62*)	14.75 (*.50*)	3.31 (*.05*)	3.04 (*.04*)	.35 (*.02*)
Early	15.13 (.82)	10.11 (.38)	3.12 (*.06*)	3.11 (*.05*)	.27 (*.02*)
Late	11.47 (.68)	8.34 (*.39*)	3.57 (*.07*)	2.98 (*.06*)	.43 (*.03*)

Note. Values in parenthesis indicate standard error of the mean.

conformity rate, there was a main effect of the number of ideas, $F(1, 130) = 14.46$, $MSE = 0.04$, $p < .001$, $\eta^2 = .10$; conformity was higher in the 112-ideas condition, consistent with Hypothesis 2. There was a main effect of time, $F(1,130) = 54.56$, $MSE = 0.03$, $p < .001$; conformity occurred at a higher rate in the late period. There was not a significant effect for the number of folders, $F(2, 130) = 0.76$, $MSE = 0.04$, $p = .470$, $\eta^2 = .30$.

We predicted that an increased number of folders would be beneficial for performance, especially in the high ideas condition (Hypothesis 3). To analyze the effects of number of ideas and number of folders, a series of 2 (number of ideas: 28 ideas, 112 ideas) × 3 (number of folders: one folder, four folders, eight folders) x 2 (time period: early vs. late) mixed ANOVAs were conducted. The means and standard errors for these conditions can be found in Table 1.

For quantity, there was a main effect of the number of ideas, $F(1, 130) = 5.57$, $MSE = 65.87$, $p = .020$, $\eta^2 = .04$; more ideas were brainstormed in the 112-ideas condition. There was a main effect of time, $F(1, 130) = 80.93$, $MSE = 9.98$, $p < .001$, $\eta^2 = .38$; more ideas were brainstormed early than late. There was not a significant effect for the number of folders, $F(2, 130) = 0.28$, $MSE = 65.87$, $p = .754$. For variety, there was a main effect of the number of ideas, $F(2, 130) = 5.84$, $MSE = 15.99$, $p = .017$, $\eta^2 = .04$; more categories were explored in the 112-ideas condition. There was a main effect of time, $F(1, 130) = 58.57$, $MSE = 4.08$, $p < .001$, $\eta^2 = .31$; more categories were explored early than late. There was not a significant effect for the number of folders, $F(2, 130) = 1.02$, $MSE = 15.99$, $p = .364$. Again, these results are consistent with Hypothesis 1 that exposure to more ideas would increase the generation of ideas and number of categories used. However, the results are

Table 2. Correlation Table for Brainstorming Measures.

	Quantity	Variety	Originality	Utility	Conformity rate
Quantity	—	—	—	—	—
Variety	.73**	—	—	—	—
Originality	.24**	−.06	—	—	—
Utility	−.15	.10	−.55**	—	—
Conformity rate	.006	.24**	−.17*	.16	—

*Note.*** Correlation is significant at the 0.01 level (two-tailed). * Correlation is significant at the 0.05 level (two-tailed).

inconsistent with Hypothesis 3 that the number of folders would have a positive impact in the high idea condition.There were no main effects of time for the number of ideas, $F(1,130) = 1.32$, $MSE = 0.20$, $p = .253$, or the number of folders, $F(2,130) = 0.75$, $MSE = 0.20$, $p = .474$. For average originality there was a main effect of time, $F(1, 130) = 67.27$, $MSE = 0.18$, $p < .001$; participants had more original ideas in the late period. There were no main effects of the number of ideas, $F(1,130) = 2.63$, $MSE = 0.37$, $p = .107$, or the number of folders, $F(2,130) = 0.21$, $MSE = 0.37$, $p = .807$. For average utility; there was a main effect of time, $F(1, 130) = 4.49$, $MSE = 0.15$, $p = .036$; participants brainstormed ideas of greater utility in the early period. There were no main effects of the number of ideas, $F(1,130) = 0.41$, $MSE = 0.25$, $p = .523$ or the number of folders, $F(2,130) = 0.71$, $MSE = 0.25$, $p = .492$. These findings are consistent with Hypothesis 4 that more original and fewer common (or more feasible) ideas would be generated in the later session.

A set of correlations were calculated for the measures of brainstorming performance using the data from the experimental conditions. These values can be found in Table 2.

Discussion

The present study sought to determine why interactive groups show enhanced productivity compared to nominal groups while engaged in EBS. The findings support the idea that increasing the number of ideas, and not the number of virtual folders, is sufficient to boost productivity. Contrary to the implications of some research findings that small group EBS can actually hinder performance, we did not find a reduced performance in the 28-ideas condition relative to the control condition. Moreover, exposing participants to 84 more ideas only enhanced performance by about six ideas. However, this

compares favorably with the increase reported in the three studies that showed positive effects of group size on ideas per person (Dennis & Valacich, 1993; Gallupe et al., 1992, Experiment 2; Valacich et al., 1994, Experiment 3). These studies showed an increase ranging from 1 to 2.5 ideas.

High idea exposure did not increase the originality and utility of the ideas in these studies. The findings in the literature are ambiguous as to the impact of EBS and group size on quality. Derosa et al. (2007) reported no overall difference in quality between nominal and interactive electronic groups. However, large interactive groups generated lower quality ideas than nominal groups while the reverse was true for small groups. Although we did not find increased quality for our low-idea condition in this study, this issue is worthy of further examination. The generation of high-quality (both original and useful) ideas requires careful processing of the shared ideas. Participants need to be motivated to process the shared ideas and build on them (De Dreu, et al., 2011; Paulus, Dzindolet, & Kohn, 2011). The problem with the EBS approach is that individuals appear to focus primarily on generating their own ideas rather than on the shared ideas (Dennis et al., 2005). This may be one reason some have found little benefit of EBS, even with large groups, as we noted in the introduction.

The results of this study clearly demonstrate that the number of ideas exposed to participants in EBS is a critical variable. In support of Hypothesis 1, exposure to a high number of ideas enhanced the number of ideas generated and the number of categories that were explored. Thus we conclude that the major factor in the benefit of large EBS groups is the exposure to a large number of ideas. Exposure to a high number of ideas presumably provides a semantic basis for the generation of additional ideas and categories of ideas. Since we controlled for quality of the ideas presented, it appears that the uniqueness of the ideas may not be an important factor, as also suggested by prior research (Connolly et al., 1993; Dugosh & Paulus, 2005). Furthermore, since the participants worked in individual rooms, social facilitation is also ruled out as a contributing factor since number of ideas was not confounded with the number of group members in the room. Because it was clear to the participants that the ideas were from past participants and were presented by a computer, feelings of competition (social comparison) should have been minimized (cf., Dugosh & Paulus, 2005). However, it is possible that social comparison may have played a role in the quantity results. Participants who receive more ideas might be motivated to engage in upwards matching. Support for a social comparison explanation is dampened to some extent by the lack of a number of ideas by number of folders interaction on quantity. If upwards matching were the primary driver of the findings, we would expect that the one folder, 112-ideas condition would have the greatest quantity given the fast rate at which that folder is propagated with ideas from the

computer. While this null result does not support social comparison theory, it is impossible to completely disentangle cognitive stimulation explanations from social matching explanations in the present study.

It is possible that the high rate of idea exposure in the 112-ideas condition may have enhanced the pace of idea generation independent of the content of the exposed ideas or of social comparison processes (Kelly, 1988). However, the measure of conformity suggests that participants were affected by the content of the ideas. Consistent with Hypothesis 2 it was found that degree of conformity to the presented ideas was greatest in the high idea exposure condition. This suggests that participants in this condition paid more attention to the presented ideas, an important factor in enhancing their impact (Dugosh et al., 2000). The increased attention may have been due to the high rate at which the ideas were presented in the 112-ideas condition. This may have increased the salience of the presented ideas and increased the likelihood that participants paid attention to at least some of them. We have also found in previous research that such conformity can enhance idea generation since those whose ideas were closely linked to the ones generated by other electronic brainstormers were the most productive (Baruah & Paulus, 2011). Essentially, it appears to be beneficial to go with the flow of the ideas presented. The increased conformity over time is consistent with the suggestion of Dennis et al. (2005) that participants may pay attention to ideas of others later in the session when they have exhausted their initial pool of ideas.

The lack of effect of number of folders was counter to Hypothesis 3 that this factor would have an important role in the impact of idea exposure. We anticipated that folders would be especially helpful in the high idea condition. The lack of impact of the folder manipulation is surprising since cognitive overload is often raised as a problem in EBS (e.g., Santanen, et al. 2004). Our study suggests that it may not be a serious problem for relatively short sessions and with the number of ideas employed in this study. Possibly with a larger number of ideas, folders may be more beneficial in mitigating any overload due to increased exposure. The lack of effect of folders also suggests that the effect of number of ideas is not due to simple expectancy effects (Schwarz, 1999). With few folders, participants would be more aware of the large number of ideas being generated.

Consistent with Hypothesis 4, more original ideas were generated late in the session and more useful ideas early in the session. Although it is often assumed that more creative ideas and less accessible ideas will occur later in an idea-generation session (Brown & Paulus, 2002), this has been demonstrated only a few times, but by different research teams (e.g., Gerlach, Schutz, Baker & Mazer, 1964; Kohn & Smith, 2011; Parnes, 1961; Ward, Patterson, Sifonis, Dodds, & Saunders, 2002)

Conclusion

This study confirms that individual brainstorming can be enhanced by exposing individuals to a large set of ideas previously generated by their peers. This is consistent with the group size effect in EBS. However, the implementation of certain procedures in the EBS process may be required to further increase its effectiveness. We have suggested that an increased emphasis on building on the ideas of others after the participants have generated a significant number of ideas may increase the number of novel ideas generated. In order to decrease the tendency of individuals to prematurely conform their ideas to their peers, it may be best for individuals to first generate ideas without access to their peers' ideas and then phase into a session where they are exposed to their peers' ideas (Baruah & Paulus, 2008; Ferreira, Antunes, & Herskovic, 2011). Other techniques such as having participants focusing on categories of a problem in sequence may also enhance the benefit of EBS (Coskun, Paulus, Brown, & Sherwood, 2000; Dennis et al., 1996).

Author's Notes

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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