

Collaborative Fixation: Effects of Others' Ideas on Brainstorming[†]

NICHOLAS W. KOHN^{1*} and STEVEN M. SMITH²

¹*The University of Texas at Arlington, USA*

²*Texas A&M University*

SUMMARY

Three experiments examined whether or not fixation effects occur in brainstorming as a function of receiving ideas from others. Exchanging ideas in a group reduced the number of domains of ideas that were explored by participants. Additionally, ideas given by brainstormers conformed to ideas suggested by other participants. Temporal analyses showed how the quantity, variety and novelty of ideas fluctuate over the course of a brainstorming session. Taking a break modulated the natural decline over time in the quantity and variety of ideas. Although fixation was observed in brainstorming in terms of conformity and restriction of the breadth of ideas, it did not influence the number of ideas generated in these experiments. Copyright © 2010 John Wiley & Sons, Ltd.

Brainstorming is a popular method for group creativity, but is inefficient. In creative problem solving individuals often face *fixation*, an impediment to productive problem solving (Duncker, 1945; Luchins & Luchins, 1959; Maier, 1931). The present study investigated if fixation takes place in brainstorming and is a contributing factor to brainstorming's inefficiency.

Osborn (1957) believed that working in groups is more effective than working individually when using his rules. Those given his brainstorming rules generate more ideas than participants not given the rules (Parnes & Meadow, 1959). Theoretically, group brainstorming should be advantageous because it allows members to share ideas (Paulus, 2000). The larger the group, the more domains related to the problem should be accessed. Furthermore, each member will have a unique cognitive architecture and will synthesize ideas differently (Stasson & Bradshaw, 1995).

Social causes of productivity deficits

There is considerable evidence that group brainstorming is less productive than individual brainstorming (Diehl & Stroebe, 1987, 1991; Mullen, Johnson, & Salas, 1991; Taylor, Berry, & Block, 1958). Typical brainstorming experiments compare performance by a group of participants ('real groups') to that of the summed effort of the same number of participants working individually ('nominal groups'). The 'productivity deficit' in

*Correspondence to: Nicholas W. Kohn, The University of Texas at Arlington, USA. E-mail: nkohn@uta.edu

[†]The present experiments were earlier reported in a dissertation by Nicholas Kohn.

brainstorming refers to nominal groups generating more non-redundant ideas than real groups. In an interactive group, each member can monitor the efforts and productivity of others, resulting in social comparison (Paulus & Brown, 2003), which might cause social loafing and social matching (Paulus & Dzindolet, 1993). Social loafing occurs when individuals give less effort in a group because responsibility is diffused (Latané, Williams, & Harkins, 1979). Social matching is a tendency to conform to peers (Asch, 1951). According to Latané's (1981) social impact theory, larger groups lead to greater conformity and greater downward performance matching. Paulus and Dzindolet (1993) found that real group partners' performance was more highly correlated than the nominal partners' performance, and that social influence developed early and was maintained throughout the session. Furthermore, group members who worry that their contributions are being evaluated might feel apprehensive about volunteering wild ideas, thus lowering their productivity. High anxiety (Camacho & Paulus, 1995) or belief that an expert is judging one's ideas (Collaros & Anderson, 1969) can lead to fewer ideas generated.

COGNITIVE CAUSES OF PRODUCTIVITY DEFICITS

Cognitive causes of productivity deficits might include production blocking (Diehl & Stroebe, 1987), excessive demands on cognitive resources and working memory (e.g. Nijstad, Stroebe, & Lodewijx, 2003), and fixation (e.g. Smith & Blankenship, 1989, 1991), a block similar to part-list cuing inhibition and output interference effects (e.g. Raaijmakers & Shiffrin, 1981; Rundus, 1973; Slamecka, 1968). Diehl & Stroebe (1987, 1991) found evidence of production blocking in brainstorming, the notion that multiple group members cannot speak at the same time. The 'non-blocking' group allowed its members to speak whenever they liked. A nominal group and the non-blocking group produced more ideas than a real group, with no difference between the nominal and non-blocking groups. Longer delays between the generation and articulation of ideas also reduce productivity (Nijstad et al., 2003). Furthermore, Paulus and Yang (2000) found that using a modified brainstorming method that allowed members to attend to fewer ideas at a time led to an increase in productivity. These findings show that productivity in normal group brainstorming can suffer because of cognitive overload (Hinsz, Tindale, & Vollrath, 1997; Nagasundaram & Dennis, 1993; Nijstad et al., 2003).

Productivity deficits in brainstorming are similar to collaborative inhibition, which is the case where a group is less effective than individuals in recalling information. Weldon and Bellinger (1997) stated that collaborative inhibition, like a brainstorming deficit, is due to many factors such as social loafing, evaluation apprehension, and production blocking. Part-list cuing inhibition may also be a cause of collaborative inhibition. Inhibition was greater for recall of lists made up of few categories containing numerous items than for recall of lists composed of numerous categories containing few items (Basden, Baden, Bryner, & Thomas, 1997), and categorical clustering was less frequent in collaborative recall than in individual recall. Collaborative inhibition occurs in groups as small as two individuals (Finlay, Hitch, & Meudell, 2000), where researchers concluded that each partner's recollections acted as part-set cues for the other.

It has been hypothesized that part-list cuing inhibition occurs when a brainstorming group member hears another's idea; hearing an idea might increase the retrieval strength of that idea in other group members, thereby blocking or inhibiting alternative ideas (Smith, 2003). This is the central question of the present study, that is whether a blocking or fixation

effect occurs in brainstorming when group members hear ideas from others, and if so, what measures of ideation are affected.

ATTEMPTS TO ELIMINATE BRAINSTORMING DEFICITS

Electronic brainstorming

In a typical electronic brainstorming system (EBS), each member has a computer console displaying ideas from other users on the monitor and providing space at the bottom of the screen for users to submit their own contributions. EBS might be a means to overcome evaluation apprehension, production blocking and basic cognitive limitations. Production blocking and cognitive load may be reduced because EBS members can submit ideas concurrently and can decide when to generate their own ideas and when to attend to others' contributions (Dennis & Valacich, 1993). Valacich, Dennis and Connolly (1994) found that when groups had nine people or greater, EBS groups produced more ideas than did nominal groups. An electronic medium can provide anonymity, thereby decreasing evaluation apprehension. An EBS condition in which group members participated anonymously produced more ideas than a condition in which each idea was tagged to its author and as many ideas as the nominal group comparison (Cooper, Gallupe, Pollard, & Cadsby, 1998).

Increasing attention

Researchers have improved group brainstorming by increasing attentional focus and motivation levels (Dugosh, Paulus, Roland, & Yang, 2000). Dugosh et al. increased attention to others' ideas by telling participants that memory for ideas would be tested. This result was found in traditional brainstorming as well as in EBS.

EFFECTS OF EXTERNAL STIMULI ON PROBLEM SOLVING

In brainstorming, ideation is theorized to be affected by external stimuli. Such stimuli have been found to affect ideation in a number of ways. For example people can obtain ideas unknowingly from others (e.g. Marsh, Landau, & Hicks, 1997), a phenomenon known as *unconscious plagiarism*. Brainstorming participants exposed to heterogeneous stimuli produce more categories of ideas, and those exposed to homogenous stimuli generate more ideas per category (Nijstad, Stroebe, & Lodewijkx, 2002). Most relevant to the present study, however, is that experimentally provided stimuli can cause *fixation*, defined as 'something that blocks or impedes the successful completion of various types of cognitive operations, such as those involved in remembering, solving problems, and generating creative ideas' (Smith, 2003, p. 16).

Classic examples of fixation in creative problem solving are Duncker's candle problem (Duncker, 1945) and Maier's two-string problem (Maier, 1931). Jansson and Smith (1991) gave designers engineering tasks, such as designing a spill-proof coffee cup, or a measuring device for visually impaired people. Half received an example diagram with design flaws, while the control groups received no examples. Examples made participants more likely to incorporate even obvious flaws in their creative designs (see also Chrysikou & Weisberg, 2005; Purcell, Williams, Gero, & Colbron, 1993). Conformity caused by viewing examples

has been shown to be unaffected by instructions to avoid conformity (e.g. Smith, Ward, & Schumacher, 1993).

Although fixation in insight problem solving, a convergent task with correct and incorrect answers, is usually seen in terms of the number of correct solutions, fixation usually manifests itself in terms of limiting the range of ideas explored, rather than the number of ideas generated, when open-ended divergent problems are used (e.g. Jansson & Smith, 1991; Smith et al., 1993). Fixation in such divergent tasks has been referred to as a *conformity* effect (Smith et al., 1993). In interactive brainstorming, rather than exploring a diverse set of ideas, participants might conform to the categories of ideas suggested by other group members. The presence of fixation in an interacting group might be indicated by a reduction in the number of categories explored, and/or a reduction of the number of ideas generated. It is important to note that conformity is not the same as social matching. Social matching is a more conscious process that leads to participants generating similar *number* of ideas, whereas conformity is a more unconscious process that leads to participants generating similar *type* of ideas.

Fixation may be overcome through incubation effects, that is putting aside a problem temporarily to deal with fixation (Wallas, 1926; Woodworth & Schlosberg, 1954). The *forgetting fixation* theory of incubation (Smith, 2003; Smith & Blankenship, 1989, 1991) is the idea that an incubation interval allows one to forget a fixating block and allow better solutions to be accessed. For example problem-solving trials in which fixation was induced have been found to benefit the most from incubation intervals (e.g. Smith & Blankenship, 1991; Vul & Pashler, 2007). Incubation effects are not universally found (e.g. Dominowski & Jenrick, 1972; Gall & Mendelsohn, 1967; Olton, 1979; Olton & Johnson, 1976), although several studies have found that incubation intervals facilitate solving insight problems (Goldman, Wolters, & Winograd, 1992; Penney, Godsell, Scott, & Balsom, 2004; Segal, 2004; Smith & Blankenship, 1989). A study on the effect of breaks on individual brainstorming found that participants in the break conditions generated more ideas in the final portion of the brainstorming session than did those in a no-break condition (Paulus, Nakui, Putman, & Brown, 2006).

Neither fixation, nor relief from fixation, has been examined in interactive brainstorming. Nijstad et al. found that presentation of homogenous stimuli led to increased category fluency (Nijstad et al., 2002) and that priming categories via pre-experiment questionnaires led to increased idea generation within these primed categories (Rietzschel, Nijstad, & Stroebe, 2007); however neither of these studies have directly tested or observed fixation. The purpose of the present study was to test whether fixation takes place in brainstorming when group members get ideas from others, whether fixation contributes to productivity deficits, and what measures of ideation reflect these effects. Experiment 1 tested productivity deficit effects in an EBS modality, and measured several ideation metrics, including quantity, variety and novelty, over the time course of the experimental brainstorming session. Fixation could manifest itself in terms of the quantity of ideas generated, the typical measure of productivity deficits, but fixation could also affect variety and novelty if idea search becomes confined to fewer categories. In Experiment 2 the fixating effect of others' ideas was experimentally tested, controlling the ideas that participants viewed. Experiment 3 tested whether incubation intervals can alleviate induced fixation in brainstorming.

EXPERIMENT 1

Experiment 1 obtained normative data on individual and group brainstorming. The norm was used for comparing production rates in Experiments 2 and 3, and for identifying

fixating stimuli to present to participants in Experiments 2 and 3. Experiment 1 manipulated group versus individual brainstorming, creating nominal groups from individuals, and assessed the quantity, variety and novelty of ideas generated over the entire brainstorming session. It was predicted that a productivity deficit would be observed, that is more ideas generated in the nominal condition than in the real group condition.

Method

Participants

Participants for this study were from an introductory psychology course. They received credit towards their experimental participation requirement of the course. A total of 160 participants volunteered for this experiment.

Materials

Four terminals were used, each with its own personal computer and monitor. AOL Instant Messenger (AIM) was the software medium for electronic brainstorming.

Design and procedure

Participants were randomly assigned to either nominal or real groups. In the nominal group condition, participants worked individually on the brainstorming task. For each nominal session, there were two to four participants present in the room. In the real group condition, four participants worked together. For both conditions, participants were seated at computer terminals in the same room, separated by divider walls that prevented visible contact with other participants.

Participants received instructions on brainstorming as well as a modified version of Osborn's (1957) brainstorming rules: (a) criticism is ruled out, (b) freewheeling is welcomed, (c) quantity is wanted, (d) combination and improvement are sought and (e) stay focused on the task. Next, participants were given the brainstorming topic ('List ways in which to improve Texas A&M University'). Similar topics have been used in other brainstorming studies (Marsh et al., 1997; Paulus et al., 2006). Participants spent 20 minutes generating as many ideas as possible AIM. For the nominal condition, participants typed ideas and transmitted them to the experimenter's computer. Participants received no communication or feedback from the experimenter during brainstorming. In the real group condition, participants communicated with each other using the 'Chat' feature of AIM. This allowed participants to see each others' ideas as they were submitted. Participants were not aware of which person in the room submitted each idea because each person was assigned a random ID.

Results

Coding

For both conditions, experimenters coded each idea generated as belonging to 1 of 30 possible categories of ideas (see Appendix for category list). The creation of categories for classification was used in a previous brainstorming study with a similar topic (Baruah & Paulus, 2008). On the rare occurrence that a submitted entry contained two ideas, this entry was divided and categorized appropriately (e.g. 'Fix the sidewalks and tear down the old buildings' would be coded as two ideas belonging to the categories 'Improvements' and

'Buildings', respectively). Repetitious ideas or non-serious ideas were not included in any analysis. Interrater reliability, as measured by Cronbach's α was .92.

To create nominal groups, the data from randomly selected participants from the nominal condition were grouped together. These ideas were placed in temporal order (e.g. Participant A's idea submitted at 14:15 was placed after Participant B's idea submitted at 14:12). For both real groups and nominal groups, any ideas repeated by another participant were discarded.

To assess responses, each idea was given a novelty score. The 80 participants in the nominal condition generated a total of 2119 coded ideas that fell into the 30 categories (see Appendix for a list of categories and frequency of ideas). Each category of idea was assigned a novelty score based on the following formula: novelty score of category $Y = (2119/\text{number of ideas falling within category } Y)/(2119/100)$. Thus, the less frequent the category was explored by participants, the higher the novelty score. For example 'Food' was the most frequently occurring category of ideas (165 ideas); any idea coded as 'Food' was assigned the lowest novelty score (0.61).

Temporal analyses were conducted by dividing each group's session (real and nominal) into four time quadrants: Q1 [0:00–4:59], Q2 [5:00–9:59], Q3 [10:00–14:59] and Q4 [15:00–20:00].

Quantity

To analyse how the group type influenced production, a 2 (group type: real vs. nominal) \times 4 (time quadrant: Q1, Q2, Q3, Q4) ANOVA was calculated on the number of ideas generated. There was a main effect of group type [$F(1, 38) = 13.04, MSE = 117.96$] with nominal groups ($M = 25.74, SE = 1.21$) producing more ideas than real groups ($M = 19.54, SE = 1.21$). The effect of time quadrant was also significant on the number of ideas produced [$F(3, 114) = 161.35, MSE = 12.29$]. Pairwise tests (with a Bonferroni adjustment) revealed that the number of ideas produced decreased with each successive time quadrant (see Figure 1). There was also a significant interaction between group type and time quadrant [$F(3, 114) = 14.30, MSE = 12.29$]. Follow-up t -tests revealed that nominal groups generated more ideas than real groups during the first time quadrant [$t(38) = 5.50, p = .00$], second time quadrant [$t(38) = 3.17, p = .00$] and third time quadrant [$t(38) = 2.16, p = .04$].

Variety

To analyse how the group type affected the variety of ideas generated, a 2 (group type: real vs. nominal) \times 4 (time quadrant: Q1, Q2, Q3, Q4) ANOVA was calculated on the number of categories explored. There was a main effect of group type [$F(1, 38) = 64.38, MSE = 13.58$] with the nominal groups ($M = 13.63, SE = .41$) exploring more categories than the real groups ($M = 8.95, SE = .41$). The effect of time was also significant [$F(3, 114) = 57.20, MSE = 3.87$]. Pairwise tests (with a Bonferroni adjustment) revealed that the number of categories explored decreased with each successive time quadrant (see Figure 2). There was also a significant interaction between group type and time quadrant [$F(3, 114) = 2.78, MSE = 3.87$]. Follow-up t -tests revealed that nominal groups generated more categories than real groups during the first time quadrant [$t(38) = 7.72, p = .00$], second time quadrant [$t(38) = 5.59, p = .00$], third time quadrant [$t(38) = 5.50, p = .00$] and fourth time quadrant [$t(38) = 5.16, p = .00$].

Novelty

To assess novelty, a 2 (group type: real vs. nominal) \times 4 (time quadrant: Q1, Q2, Q3, Q4) ANOVA analysed the average novelty of participants' ideas. This dependent measure was

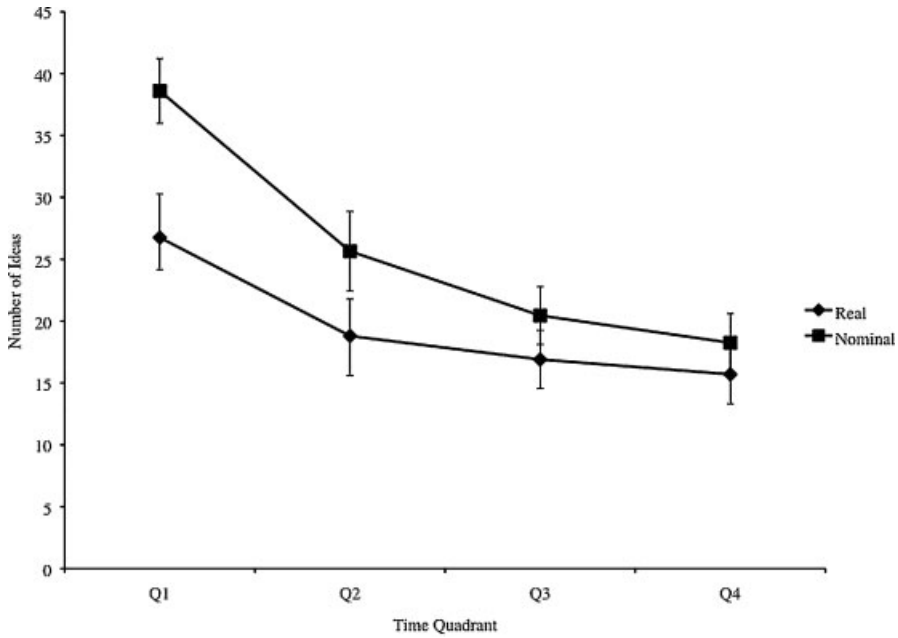


Figure 1. Quantity of ideas generated in Experiment 1

calculated by averaging the novelty scores of the ideas generated in each individual time period. The effect of time was not quite significant [$F(3, 114) = 1.81, MSE = 0.62, p = .15$]; however, there was a statistical trend of novelty scores increasing with each successive time quadrant. There was no main effect of group type [$F(1, 38) < .01$,

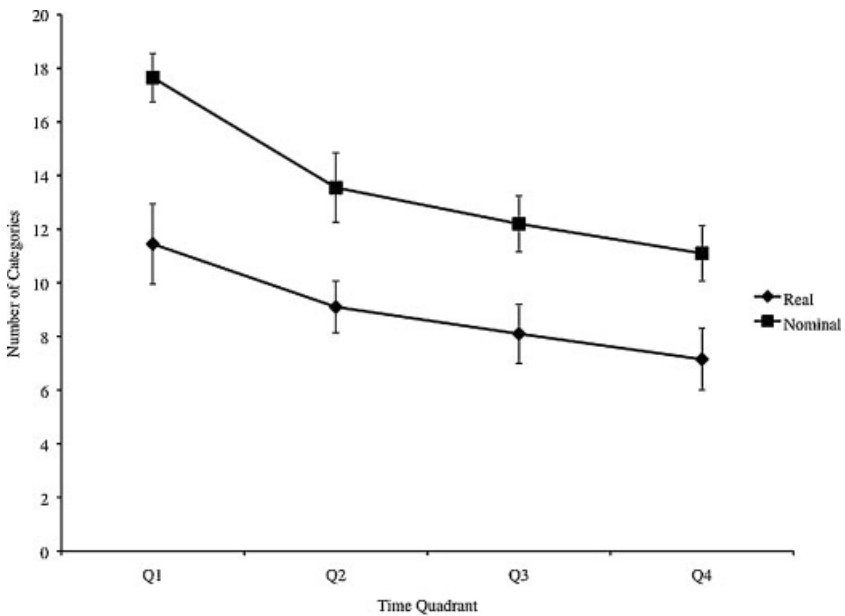


Figure 2. Variety of ideas generated in Experiment 1

$MSE = 0.70$] and there was no significant interaction between group type and time quadrant [$F(3, 114) = 0.73$, $MSE = 0.62$].

Fluency

Ideas generated were also analysed using category depth. Category depth refers to how many ideas a participant generated within a category (Nijstad et al., 2002). In Experiment 1, category depth was calculated by dividing the number of ideas generated by the number of categories explored. A 2 (group type: nominal vs. real) \times 4 (time quadrant) ANOVA calculated on category depth showed real groups ($M = 2.20$, $SE = .08$) to have greater category depth than nominal groups ($M = 1.85$, $SE = .08$) [$F(1, 38) = 9.83$, $MSE = 0.50$, $p < .01$]. Additionally, there was a main effect of time quadrant [$F(3, 114) = 8.63$, $MSE = 0.14$; $p < .01$]; there was greater category depth in the first time quadrant than the last three quadrants. There was also a significant interaction [$F(3, 114) = 3.23$, $MSE = 0.14$; $p = .03$]; Tukey's pairwise tests revealed that category depth was greater in real groups than in nominal groups in quadrant 3 and quadrant 4.

Discussion

In Experiment 1, participants generated ideas either individually or in a group. Consistent with previous studies (Diehl & Stroebe, 1987, 1991; Gallupe, Bastianutti, & Cooper, 1991), a productivity deficit was observed; nominal groups generated more ideas than did real groups. In the first 5 minutes of the brainstorming session, nominal groups generated 44% more ideas than did real groups. However, over time this difference decreased. In the last 5 minutes of the session, nominal groups generated 16% more ideas than the real groups. This finding mirrors patterns found in previous research (Coskun, Paulus, Brown, & Sherwood, 2000) and suggests that brainstorming sessions might be optimal if a group session follows an individual session, an idea opposite to unpublished research that found that a group-to-alone sequence led more overall ideas than an alone-to-group sequence (Putman, Paulus, Dugosh, & Coskun, 1999).

The productivity deficit has always referred to the disparity in the number of ideas generated. A productivity deficit also can be seen in the number of categories explored; nominal groups generated a greater variety of ideas. There was also a temporal effect on the number of categories explored. Participants explored the most categories in the beginning of the session and this number steadily decreased with time. Similar to quantity, the greatest disparity in variety between the nominal and real groups occurred in the beginning of the session (nominal groups generated 54% more categories in the first 5 minutes). However, unlike quantity, this disparity did not decrease over the course of the entire 20 minutes (nominal groups generated 55% more categories in the last 5 minutes).

The category depth results showed that real groups go deeper into categories than nominal groups, particularly in later part of the session. This coupled with the temporal data on quantity and variety shows that over time quantity and variety decrease; however, nominal groups are better at distributing their ideas over a wider range of categories. Thus, it seems likely that real groups, relative to nominal groups are more fixated towards the end of the session. Additionally, based on Nijstad et al. (2002), our fluency results would suggest that participants in real groups are generating homogenous ideas.

The impact of novelty is usually measured in terms of number of ideas explored (see Paulus, 2000 for a review of literature examining novelty). Experiment 1 used an objective

measure of novelty, the statistical infrequency of ideas. It was predicted that nominal groups would generate more novel ideas than would real groups, because exchanging ideas by members of a group might lead to conformity of domains explored, thereby reducing the novelty of ideas. While the variety of categories was limited in a group setting, this did not result in a reduction in the novelty of ideas generated. Although not significant, a pattern was observed in that the average novelty increased with time, while quantity and variety declined. This novelty result parallels the trend seen when people generate members of categories; category exemplars that most readily come to mind, that is the most typical members are the first to be generated (Ward, Sifonis, & Wilkenfeld, 1996).

In Experiment 1 a productivity deficit was observed; nominal groups generated more ideas than did real EBS groups. Real groups generated a more limited variety of ideas. This supports the notion that exchanging ideas in a group leads members to become fixated on their peers' ideas, thus reducing the number of categories explored.

EXPERIMENT 2

Experiment 2 explored the possibility that provocative stimuli can lead to fixation in brainstorming. It was hypothesized that an idea generated in a brainstorming group could cause another group member to become fixated upon this idea. Subsequent ideas would then contain elements of this original verbalized idea, limiting the domains explored. To test this, Experiment 2 used a paradigm in which participants believed they were brainstorming with a partner. In reality, they were electronically interacting with a confederate who transmitted typical ideas to participants during the session. This method was used so that the stimuli exposed to participants could be controlled. The number of typical ideas transmitted to participants was manipulated between-subjects. It was predicted that increasing the number of typical ideas from the confederate would lead to a higher proportion of participant ideas that belonged to the same categories as the exemplified ideas. Furthermore, viewing more typical ideas should lead to fewer categories explored and a decrease in the originality of ideas. Lastly, Experiment 2 explored whether or not fixation is a contributing factor in the productivity deficit. It was predicted that the more ideas received from the confederate, the greater the fixation, and in turn, the fewer ideas generated by participants. An alternative prediction was that by exposing participants to ideas from the exemplified categories would reduce the available pool of ideas for participants to use from these categories, thus reducing the likelihood that participants would generate ideas in these exemplified categories (less conformity).

Method

Participants

Participants for this study were from an introductory psychology course and received credit towards their experimental participation requirement of the course. A total of 86 participants volunteered for this experiment. Six participants' data were not included due to either a computer error or the participant being aware of the confederate. The remaining 80 participants were randomly assigned to 1 of the 4 conditions. The confederate was a Caucasian male undergraduate student who was in the same age range as the actual participants.

Materials

Three computer terminals with AIM were used for Experiment 2.

Design and procedure

Participants were evenly divided into four conditions: 1 example, 4 examples, 10 examples or 20 examples.

At the start of the experiment the experimenter welcomed the participant and the confederate into the laboratory. Upon arrival, both the participant and the confederate received instructions that they would be brainstorming together on a topic using AIM. Additionally, the instructions informed them that:

‘The program is set-up so that it will randomly screen-out some of your partner’s ideas and some of your ideas. Although the experiment will record all of your ideas that you submit and all of the ideas that your partner submits, you will only be able to view some of your partner’s ideas. Therefore, AIM will tell you when your partner is typing; however, it is possible that their idea may not appear in your chat window’.

Included in these instructions were the same rules on brainstorming given in Experiment 1. Next, the participant and confederate were told that one of them would be randomly taken to the adjacent laboratory room that had a computer. The confederate was led to the adjacent room which had a computer with an AIM connection. A ‘chat’ session was established on AIM that included the experimenter, the participant and the confederate. After 1 minute, the experimenter returned to the original room and seated the participant at the computer terminal. Next, participants were given the brainstorming topic (‘List ways in which to improve Texas A&M University’). They then spent the next 20 minutes generating as many ideas as possible.

Upon conclusion of the experiment, participants were asked if they were aware that the other participant was a confederate.

During the brainstorming session, the confederate transmitted ideas to the participant. Depending upon the condition, participants received 1, 4, 10 or 20 ideas. These ideas are from the categories that were the highest in frequency (most typical) in Experiment 1 (see Appendix). For example in the one-example condition, participants would receive only the idea ‘Add more busses to off-campus routes’ from the category ‘Transportation’. If the participant had already generated this exact idea, an alternate idea from the same category was given. In addition to submitting the ideas as the pre-determined times, the confederate would type something every 40 seconds but not submit it. Thus, the participant would see that the confederate was generating ideas throughout the duration of the brainstorming session. This was done to increase believability.

Participants in the one-example condition received one idea from the Transportation category. Participants in the four-example condition received four ideas (one from each of the four most frequently-occurring categories). Participants in the 10-example condition received 10 ideas (one from each of the 10 most frequently-occurring categories). Participants in the 20-example condition received 2 ideas from each of the 10 categories exemplified in the 10-example condition. The reason two ideas per category were used in this last condition was to test whether fixation could be increased relative to the 10-example condition by doubling the amount of exposure per category.

Results

Coding

Every idea generated by participants was classified as belonging to 1 of the 30 categories used in Experiment 1 (except for vague/uncodable ideas which were not included in the analyses). Like Coskun et al. (2000), the data in Experiment 2 were analysed in terms of 2-minute time periods (0–1:59, 2:00–3:59, 4:00–5:59, 6:00–7:59, 8:00–9:59, 10:00–11:59, 12:00–13:59, 14:00–15:59, 16:00–17:59, 18:00–20:00). These time periods were created to match the 10-example condition, where participants received an idea from the confederate every 2 minutes.

Quantity

To analyse how the number of submitted confederate ideas influenced the number of ideas generated by participants, a 4 (condition: 1 example, 4 examples, 10 examples, 20 examples) \times 10 (time period) ANOVA was calculated on the number of ideas generated. There was no main effect of condition [$F(3, 76) = 1.15, MSE = 12.35$]. A main effect of time period was observed [$F(9, 684) = 35.03, MSE = 1.32$]. Pairwise comparisons (with a Bonferroni correction) revealed that there were more ideas generated in the first 2 minutes than the other nine time intervals (see Figure 3). There was no difference in the number of ideas in the second, third, fourth and fifth time periods; however, more ideas were generated in these time periods than all of the later time periods. Overall, there was a trend that the number of ideas generated decreased as the brainstorming session continued (see Figure 3). The interaction between condition and time period was not significant [$F(27, 684) = 0.53, MSE = 1.32$].

Conformity analysis

To assess if fixation, as defined by conformity, was occurring, Experiment 2 used a measure called ‘adjusted conformity score’. It would be an unfair comparison to calculate

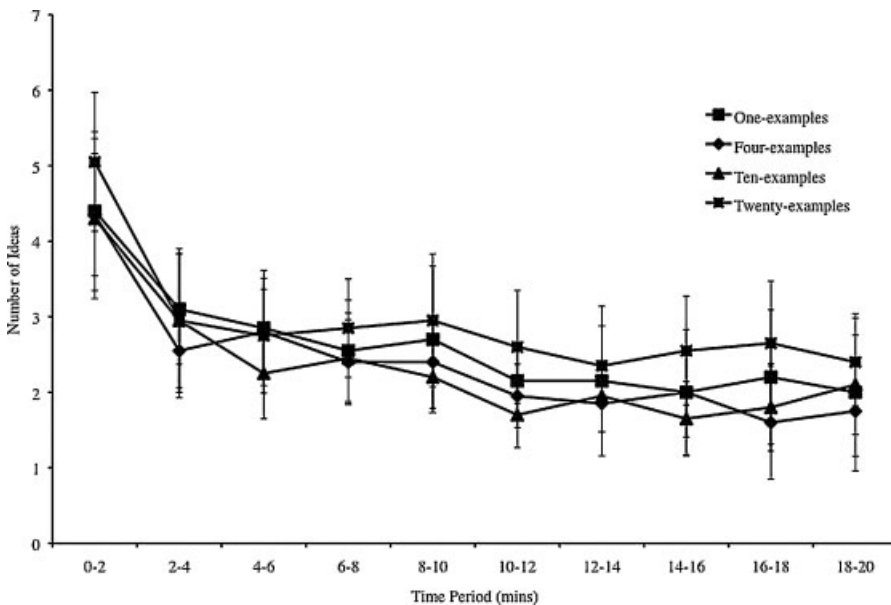


Figure 3. Quantity of ideas generated in Experiment 2

the proportion of ideas that belong to the categories exemplified by the confederate because the denominator would differ across the four conditions (1, 4, 10 or 20). Therefore, an adjusted conformity score was calculated by taking the reciprocal of 'non-conformity' (the proportion of their ideas that belonged to the 20 categories not exemplified in any of the four conditions). This is a more fair comparison because the denominator of non-conformity (20) is the same across all four conditions. For example if a participant generated 30 ideas, of which six belonged to the 20 non-exemplified categories, then that participant's adjusted conformity score would be .80.

A 4 (condition: 1 example, 4 examples, 10 examples, 20 examples) \times 10 (time period) ANOVA compared adjusted conformity. There was a main effect of condition [$F(3, 48) = 5.42$, $MSE = 0.22$]. Pairwise tests (with a Bonferroni correction) found that participants in the 20-example condition ($M = .76$, $SE = .04$) conformed at a higher rate than did participants in the one-example condition ($M = .54$, $SE = .04$) and a marginally ($p < .10$) greater rate than the 4-example condition ($M = .62$, $SE = .04$). Overall, there was a trend of greater conformity with more examples provided. While there was a trend of conformity decreasing with time, there was no significant main effect of time period [$F(9, 432) = 1.27$, $MSE = 0.10$]. The analysis revealed a significant interaction of condition and time period [$F(27, 432) = 1.59$, $MSE = 0.10$]. Using Tukey's test, we found significant differences in adjusted conformity scores for the following time intervals: 2–4 min: 4/10/20 examples $>$ 1 example; 8–10 min: 20 examples $>$ 1 example; 10–12 min: 10/20 examples $>$ 1 example; 12–14 min: 10/20 examples $>$ 1 example and 20 examples $>$ 4 examples; 14–16 min: 20 examples $>$ 1/10 examples; 16–18 min: 20 examples $>$ 4 examples.

Variety

To analyse how the number of confederate ideas influenced the variety of ideas generated by participants, a 4 (condition: 1 example, 4 examples, 10 examples, 20 examples) \times 10 (time period) ANOVA was calculated on the number of categories explored. There was no effect of condition [$F(3, 76) = 0.80$, $MSE = 5.26$]. A main effect of time period was observed [$F(9, 684) = 35.55$, $MSE = 0.88$]. Pairwise comparisons (with a Bonferroni correction) revealed that there were more categories explored in the first 2 minutes than the other nine time intervals (see Figure 4). There was no difference in the number of categories explored in the second, third, fourth or fifth time periods; however, more categories were explored in these time periods than all of the later time periods. Overall, there was a trend that the number of categories explored decreased as the brainstorming session continued. The interaction between condition and time period was not significant [$F(27, 684) = 0.64$, $MSE = 0.88$].

Novelty

To assess the impact of the number of submitted confederate ideas on novelty, a 4 (condition: 1 example, 4 examples, 10 examples, 20 examples) \times 10 (time period) ANOVA was calculated on the average novelty of participants' ideas. There was a main effect of condition [$F(3, 48) = 7.82$, $MSE = 3.42$]. Pairwise tests (with a Bonferroni correction) found that the ideas generated by participants in the 1-example condition ($M = 2.19$, $SE = .17$) had a higher average novelty score than the ideas generated by participants in the 4-example condition ($M = 1.38$, $SE = .16$), 10-example condition ($M = 1.36$, $SE = .17$) and 20-example condition ($M = 1.14$, $SE = .15$). There was no effect of time period [$F(9,$

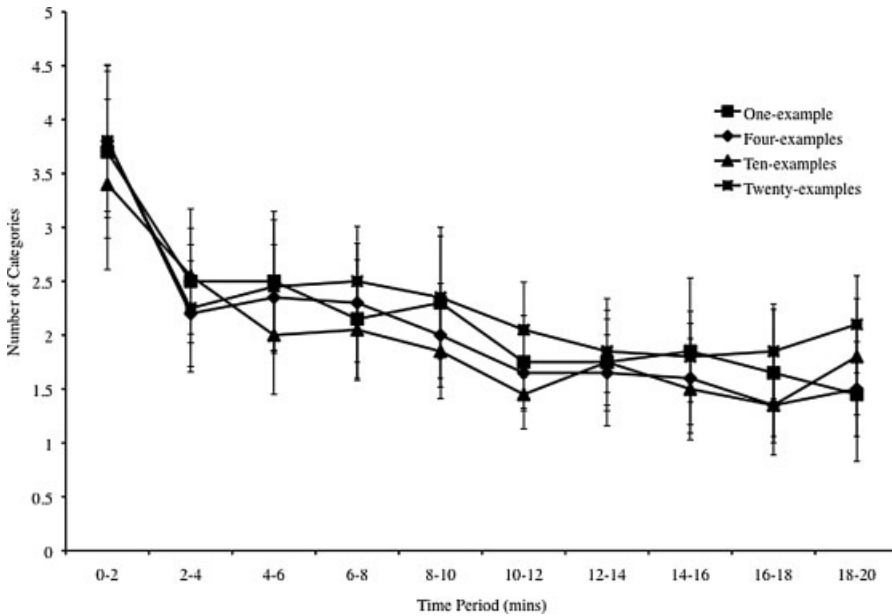


Figure 4. Variety of ideas generated in Experiment 2

432) = 0.53, $MSE = 2.34$] nor an interaction between the two variables [$F(27, 432) = 0.96$, $MSE = 2.34$].

Fluency

Category depth in Experiment 2 was calculated by dividing the number of ideas generated in the exposed category(s) by the number of exposed category(s) during the entire 20 minutes. A one-way ANOVA revealed no main effect of condition [$F(3, 76) = 1.24$, $MSE = 0.96$, $p = .30$].

Discussion

Experiment 2 examined if fixation could be induced in brainstorming by controlling the ideas to which a participant was exposed. It was predicted that increasing the amount of exposure to typical ideas would cause the individual to become more fixated on these typical ideas.

Increasing the number of typical ideas a participant was exposed to resulted in increased conformity. This result is consistent with the present hypothesis and mirrors the results of other studies that have witnessed participants' conformity to provided examples (e.g. Jansson & Smith, 1991; Smith et al., 1993). Whereas Rietzschel et al.'s (2007) findings suggested that priming could lead to exploration, we were able to directly show that fixation can arise from exchanging ideas.

While the amount of conformity increased with the number of examples provided, the quantity and variety analyses did not follow the same pattern. There were no significant differences among the four conditions on either quantity or variety. Thus, these results do not support the hypothesis that fixation contributes to the productivity deficit in terms of

quantity of ideas generated. In fact, the number of ideas and the number of categories explored by a participant in Experiment 2 was nearly the same as a single individual's in Experiment 1. The quantity and variety results of Experiment 2 differ from the findings of Nijstad et al. (2002). Nijstad observed that exposing participants to categories increased variety and productivity. The reason for the disparity is likely due to our use of high-frequency categories – categories which participants would likely explore regardless of exposure.

Novelty, however, did fluctuate as a function of the number of provided examples. As the number of typical examples increased, the average novelty of participants' ideas decreased, consistent with the conformity scores. The more a participant remains fixated within typical categories, the less novel the ideas they will generate. Compared with the 20-example participants, those in the 1-example condition generated ideas with a novelty score 92% greater.

If fixation were defined in terms of conforming to others' ideas, then one could conclude that Experiment 2 observed fixation in a group brainstorming setting. While fixation did occur, it did not have the predicted result of reducing the number of ideas generated. Participants became stuck within the exemplified categories, generating a high proportion of their ideas within these categories. However, participants still generated ideas in non-exemplified categories. It is just that as the number of exemplars increased, participants spent less time generating ideas in these more remote categories, and generated a higher proportion of ideas within the exemplified categories. Thus, Experiment 2 undermines the hypothesis that fixation contributes to the productivity deficit, as it has been defined historically.

EXPERIMENT 3

Experiment 3 investigated ways to resolve fixation during brainstorming. It is possible that a break during brainstorming will allow an individual or a group to be more productive in generating ideas during the session. A previous study (Paulus et al., 2006) found that incubation intervals increased productivity. However, their control and experimental groups were not given equivalent initial ideation time, thus not providing a fair comparison. We corrected this methodological error in Experiment 3. The present experiment also tested the forgetting fixation theory of incubation, which states that an incubation interval is helpful in that it removes fixation, allowing resolution of the problem to occur (Smith & Blankenship, 1991). It was predicted that incubation intervals would benefit production and alleviate fixation more in situations in which fixation was induced in the brainstorming session. Experiment 3 manipulated the inducement of fixation as well as the presence of breaks during the session.

Method

Participants

Participants for this study were from an introductory psychology course and received credit towards their experimental participation requirement of the course. A total of 91 participants volunteered for this experiment. Eleven participants' data were not included in the analyses due to technical issues or participant's suspicion of the confederate. The remaining 80 participants were randomly assigned to 1 of the 4 conditions. The confederate

was a Caucasian female undergraduate student who was in the same age range as the actual participants.

Materials

Three computer terminals with AIM were used for Experiment 3. For the conditions involving breaks, a packet of six mazes was used as a filler task.

Design and procedure

Participants were randomly assigned to one of four conditions: fixating-immediate, fixating-delayed, control-immediate or control-delayed. The procedure for Experiment 3 was identical to Experiment 2, with the following exceptions. In the two fixating conditions, participants received an idea from the confederate at the 10-second, 3-minute, 6-minute and 9-minute mark of the brainstorming session. Participants in the control conditions did not receive any ideas from the confederate. In the immediate conditions, participants generated ideas for 20 minutes without interruption. In the delayed conditions, participants were told to stop after 10 minutes and were not given any indication that they would return to the brainstorming task later. They were then seated at a desk and asked to complete as many mazes as possible. After 5 minutes, participants were returned to the computer terminal and asked to continue brainstorming on the same topic. They were asked not to submit any previously generated ideas. The second brainstorming session ended after 10 minutes. The confederate engaged in typing (but not submitting) during both 10-minute sessions. Upon conclusion of the subjective report, participants were asked if they were aware that the other participant was a confederate.

Results

Coding

Every idea generated by participants was classified as belonging to one of the 30 categories used in Experiment 1 (except for vague/uncodable ideas which were not included in the analyses). Like previous break studies (e.g. Paulus et al., 2006) data from after the break was analysed separately. Thus, ideas were analysed in terms of the first 10 minutes and the last 10 minutes.

Analyses of the first 10 minutes

The first set of analyses was done to assess whether or not the confederate in the fixating conditions induced fixation. In Experiment 3, no adjustment was needed for calculating conformity scores. Therefore, conformity was the proportion of participants' ideas that belonged to the four categories exemplified in Experiment 3. Participants in the fixating conditions ($M = .38$, $SD = .16$) had higher conformity during the first 10 minutes (proportion of their ideas that belonged to the categories exemplified by the confederate) than participants in the control conditions ($M = .30$, $SD = .15$); $t(78) = 2.48$, $p = .02$.

There was no significant difference between the fixating conditions ($M = 14.50$, $SD = 7.77$) and the control conditions ($M = 12.50$, $SD = 5.98$) in the number of ideas generated in the first 10 minutes; $t(78) = 1.29$, $p = .20$.

Variety was analysed with a 2 (examples: fixating vs. control) \times 2 (retest: immediate vs. delayed) ANOVA on the number of categories explored in the first 10 minutes. There was no main effect of examples [$F(1, 76) = 0.21$, $MSE = 8.39$] nor an interaction of examples and retest [$F(1, 76) = 1.17$, $MSE = 8.39$]. To check that there were no individual

differences within the two control conditions and the two fixating conditions, two planned comparisons were conducted. There was no significant difference between the control-immediate ($M=7.95$, $SD=2.91$) and the control-delayed ($M=8.55$, $SD=3.59$) conditions in the number of categories explored in the first 10 minutes; $t(38)=0.58$, $p=.57$. However, participants in the fixating-delayed condition ($M=9.55$, $SD=2.56$) explored more categories in the first 10 minutes than the fixating-immediate condition ($M=7.55$, $SD=2.35$); $t(38)=2.56$, $p=.02$.

Although numerically greater, the average novelty of ideas generated by participants in the control conditions in the first 10 minutes ($M=1.42$, $SD=1.27$) was not significantly different from the average novelty of ideas of participants in the fixating conditions in the first 10 minutes ($M=1.08$, $SD=0.23$); $t(78)=1.66$, $p=.11$.

Category depth in Experiment 3 was calculated by dividing the number of ideas generated in the four exposed categories by four. A *t*-test contrasted category depth in the first 10 minutes for fixating and control conditions. Levene's test showed that equal variances were not assumed, therefore a correction was made. Participants in the fixating conditions ($M=1.43$, $SD=1.02$) had greater category depth than participants in the control conditions ($M=0.90$, $SD=0.55$); $t(60)=2.90$, $p<.01$.

Analyses of the last 10 minutes

To see if an incubation interval increased the quantity of ideas of participants, a 2 (examples: fixating vs. control) \times 2 (retest: immediate vs. delayed) ANOVA was calculated on the number of ideas generated in the last 10 minutes. There was a main effect of retest [$F(1, 76)=5.71$, $MSE=35.33$]; 40% more ideas were generated in the delayed conditions than in immediate conditions (see Table 1). No main effect of examples was observed [$F(1, 76)=2.32$, $MSE=35.33$]; however, there was a significant interaction of examples and retest [$F(1, 76)=5.89$, $MSE=35.33$]. Planned comparisons found that 86% more ideas were generated in the fixating-delayed condition than in the fixating-immediate condition; $t(38)=3.10$, $p<.01$. There was no difference between the control-delayed condition and the control-immediate condition; $t(38)=0.03$, $p=.98$.

To assess incubation effects on the variety of ideas, the number of categories explored in the last 10 minutes was analysed. Given the unexpected result that there was a difference in the variety for the two fixating conditions in the first 10 minutes, an ANCOVA was calculated. A 2 (examples: fixating vs. control) \times 2 (retest: immediate vs. delayed) ANCOVA was calculated on the number of categories explored in the last 10 minutes with the number of categories explored in the first 10 minutes used as the covariate. There was no main effect of examples [$F(1, 75)=0.06$, $MSE=6.07$] nor a main effect of retest [$F(1, 75)=0.58$, $MSE=6.07$]. A significant interaction of examples and retest was observed [$F(1, 75)=4.45$, $MSE=6.07$]. Planned comparisons found that 57% more categories were

Table 1. Brainstorming performance in the last 10 minutes for Experiment 3

	Immediate retest	Delayed retest
Quantity		
Fixating	7.45 (4.63)	13.85 (7.98)
Control	8.65 (5.25)	8.60 (5.35)
Variety		
Fixating	5.10 (2.51)	8.00 (3.43)
Control	6.40 (2.76)	6.05 (3.52)

Standard deviations of the mean are shown in parentheses.

explored in the fixating-delayed condition than in the fixating-immediate condition; $t(38) = 3.05, p < .01$ (see Table 1). There was no difference between the control-delayed condition and the control-immediate condition; $t(38) = 0.35, p = .73$.

To assess incubation effects for the novelty of ideas, a 2 (examples: fixating vs. control) \times 2 (retest: immediate vs. delayed) ANOVA was calculated on the average novelty in the last 10 minutes. There was no main effect of retest [$F(1, 75) = 0.19, MSE = 1.56$], examples [$F(1, 75) = 0.34, MSE = 1.56$], nor an interaction [$F(1, 75) = 0.01, MSE = 1.56$].

To assess incubation effects on conformity, a 2 (examples: fixating vs. control) \times 2 (retest: immediate vs. delayed) ANOVA was calculated on the conformity in the last 10 minutes. There was no main effect of retest [$F(1, 75) = 0.90, MSE = 0.04$] or of examples [$F(1, 75) = 0.83, MSE = 0.04$]. There was no interaction of examples and retest [$F(1, 75) = 1.99, MSE = 0.04$].

To assess fluency, a t -test compared fixating and control conditions on average category depth of the four exposed categories. Category depth was marginally greater in the fixating conditions ($M = 0.87, SE = .78$) than in the control conditions ($M = 0.61, SE = .45$); $t(78) = 1.85, p = .07$.

Discussion

As evidenced by the conformity and fluency analyses for the first 10 minutes of the sessions, fixation was successfully induced. Participants in the fixating conditions had more ideas from the exemplified categories. Experiment 2 showed that fixation fluctuated with the amount of typical ideas received; however, there was no comparison condition in which participants received zero ideas from a confederate. In Experiment 3, a clear fixation effect was observed, comparing fixating conditions to the control conditions.

As in Experiment 2, exposure to others' ideas did not influence the number of ideas generated in Experiment 3. There was no difference between the control and fixating conditions in the first 10 minutes. Similarly, exposure did not cause a change in the number of categories explored. This result also mirrored the findings in Experiment 2. These findings, along with the conformity analysis, support the conclusion from Experiment 2 that exposure to others' ideas does not reduce the number of categories explored. Rather, exposure induces one to spend more time and resources generating ideas in the categories that are exemplified.

Incubation intervals influenced brainstorming in the fixating conditions differently than in the control conditions. In all three experiments, over time the number of ideas generated and the number of categories explored decreased. In the last 10 minutes of brainstorming in Experiment 3, there were more ideas generated and more categories explored in the fixating-delayed condition than in the fixating-immediate condition. There was no difference between the two control conditions on these two dependent measures. This paints a rather striking picture; if one becomes fixated during brainstorming, the presence of an incubation period has the effects of reducing the natural drop-off in quantity and variety. These results lend support for the forgetting fixation theory of incubation, which predicts incubation effects only when one has become initially fixated (Smith & Blankenship, 1989, 1991).

In summary, Experiment 3 again found that fixation, as measured by conformity, occurs when a person is presented with ideas from another individual. An incubation interval is only effective if the person was initially fixated. However, given that the vast majority of brainstorming is conducted by having two or more people exchanging ideas, the results from Experiment 3 indicate that incubation intervals could be a beneficial addition to brainstorming sessions.

GENERAL DISCUSSION

A productivity deficit was observed in Experiment 1, consistent with numerous studies (e.g. Diehl & Stroebe, 1987, 1991; Gallupe et al., 1991; Mullen et al., 1991); nominal groups generated more non-redundant ideas than did real groups. The use of AIM as an EBS medium yielded results similar to findings of previous studies (e.g. Gallupe et al., 1991). Fixation in brainstorming was observed in Experiment 2; people conformed to ideas to which they were exposed, and the rate of conformity increased as the number of ideas exposed increased. Experiment 3 used a control comparison and found that participants exposed to another's ideas were more likely to conform than participants who did not see others' ideas. Research on productivity deficits in brainstorming has focused on the quantity of ideas generated by real and nominal groups. In the present study productivity was examined temporally. The disparity between the real and nominal groups in the number of ideas was greatest in the beginning of the session. Nominal groups outperformed real groups throughout the course of the brainstorming session, but the difference decreased over time. Experiment 2 found that fixation increased with the amount of exposure when measured by conformity, but not when measured by the number of ideas generated. Thus, although fixation effects in brainstorming clearly occur, our evidence does not show that fixation causes the classic productivity deficit. Experiments 2 and 3 used situations involving a single participant plus one confederate, whereas most brainstorming sessions involve more than two people. It is possible that exposure from more team members (e.g. three, instead of only one), or a stronger emphasis on new ideas, could lead to clearer quantity-measured productivity deficits. Latané's social impact theory (1981) suggests that this is likely.

It had been predicted that exchanging ideas would limit the range of domains of ideas. In Experiment 1 real groups explored fewer categories of ideas than did nominal groups. Furthermore, increasing exposure to typical ideas led to less novel ideas. The ideas presented to participants originated from the most typical categories of ideas for the brainstorming topic. Participants conformed to these ideas at a high rate, lowering the novelty of their own ideas. Although the present experiments are not a direct test of the model proposed by Paulus and Brown (2007), the results are clearly consistent with their view that ideas are semantically related. Thus, concepts that are more closely related to the active idea (in our case, the exposed idea) are more likely to be in turn activated (Brown & Paulus, 2002).

Experiment 1 showed a decline in the number of ideas generated over time, which occurred at a different rate for nominal and real groups. Over time there was a decline in the number of categories explored by individuals as well as groups. The novelty of ideas increased slightly over time in Experiments 1 and 2, although the conflicting results from Experiment 2 make this pattern less clear.

Incubation effects were found in Experiment 3, but they were modulated by whether or not participants had been exposed to another's ideas. For typical brainstorming groups, where exposure to others' ideas is the norm, it may be that session breaks could keep a group generating numerous ideas and a wide range of them. Furthermore, a break appears to enhance the natural rise in novelty over time.

One of the proposed benefits of brainstorming is that it promotes mutual stimulation. Hearing others' ideas should allow group members to explore new categories that otherwise might have been not explored. Furthermore, 'piggybacking' might occur where one builds ideas off another group member's idea. The results from the present study offer mixed findings in regard to these predictions. Experiment 2 showed that piggybacking did take place as participants generated a large proportion of ideas in the same categories as

those exemplified by the confederate. However, Experiment 1 contradicts the prediction that mutual stimulation leads to more domain exploration; interacting real groups explored fewer categories than did non-interacting nominal groups.

The forgetting fixation theory of incubation states that incubation effects are due to resolving fixation; resolution is facilitated when fixated ideas are forgotten during the incubation interval. Thus, the theory predicts that incubation effects will be present when participants become fixated. Supportive findings for this theory have been in insight problem solving (e.g. Smith & Blankenship, 1989, 1991) and memory retrieval (Smith & Vela, 1991). The present study lends more support to the forgetting fixation theory because in the present experiments incubation periods were beneficial only when participants were initially fixated.

There is a possible alternative explanation for the findings of fixation. Perhaps participants thought the confederate's ideas were good, so they felt social pressure to conform to these ideas. To test this alternative explanation, it would be necessary to ask participants for ideas that are as different as possible from their peers or to explicitly criticize those ideas. Such manipulations have been used in others studies of fixation (e.g. Smith et al., 1993). If conformity were seen in those circumstances, then social explanations for conformity could be ruled out.

The findings in the present study suggest that changes to the structure of brainstorming sessions could be beneficial. Assuming it is desirable to have a wide variety of ideas or solutions to a problem, or to generate a unique idea, then one should split up the brainstorming group into non-interacting individuals, avoiding a group session. Given that novelty slightly rises with time, the brainstorming session needs to be of adequate length. On the other hand, if the goal is to explore a few categories in depth, then interaction among the members should be encouraged. Also, taking a break might help alleviate fixation, leading to an improvement in ideation, especially in terms of the quantity and variety of ideas.

The present study revealed several new findings. Fixation was found when brainstorming participants were exposed to others' ideas. Fixation led to a reduction in an objective measure of the novelty of ideas. Temporal analyses provided insight into how various measures (quantity, variety, novelty) fluctuate over the course of a brainstorming session. Finally, this study showed that taking a break could increase the effectiveness of a brainstorming session.

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APPENDIX

Categories used in the three experiments. Frequency and novelty scores are based on individuals in Experiment 1.

Category	Frequency	Novelty score
Expansion	3	33.33
Employment	4	25.00
Volunteer	9	11.11
Publicity	13	7.69
Health	19	5.26
Corps	23	4.35
Library	28	3.57
Admissions	31	3.23
Organizations	35	2.85
Tutors	43	2.33
Diversity	43	2.33
Rec	44	2.27
Advisors	47	2.13
Beautification	48	2.08
StudentLife	51	1.96
Traditions	54	1.85
Teachers	60	1.67
Safety	66	1.52
Entertainment	70	1.43
Tech	87	1.15
Costs	99	1.01
Academics	103	0.97
Improvements	119	0.84
Buildings	124	0.81
Dorms	125	0.80
Parking	131	0.76
Class	146	0.68
Sports	157	0.64
Food	165	0.61
Transportation	172	0.58