Alternating Individual and Group Idea Generation: Finding the Elusive Synergy

Runa Korde and Paul B. Paulus

The University of Texas at Arlington

Address for correspondence:

Paul B. Paulus

Department of Psychology

University of Texas at Arlington

Arlington, Texas 76019-0528

Email: Paulus@uta.edu

Abstract

Three experiments were designed to test the efficacy of ideation procedures that involved alternation of individual and group idea generation sessions (hybrid brainstorming) as compared to traditional individual and group ideation. The hybrid condition led to the best performance in terms of number of ideas generated. This effect was strongest in comparison to the group condition. A meta-analytic comparison involving all three experiments indicated that the hybrid condition outperformed both the alone and the group conditions. Since after each group idea exchange session there was an enhancement in the number of ideas generated in the alone session, the pattern of performance in the hybrid condition supported the cognitive perspective of group creativity (Nijstad & Stroebe, 2006; Paulus & Brown, 2007). Social cues in the form of the co-presence of other participants in the alone condition, the addition of practice sessions to all conditions, and an additional phase did not change the pattern of results. The results of the experiments support the original suggestion by Osborn (1953) that the most effective brainstorming process is one that involves a variation in individual and group ideation.

Keywords: group creativity, brainstorming, innovation, brainwriting, creativity, synergy

Highlights

Alternating individual and group ideation was better than group ideation.

Alternating individual and group ideation was better than solitary ideation.

The benefits of alternation are only evident in the alone sessions.

The results provide evidence for the synergistic benefits of group ideation.

The results support an association model of group ideation.

Collaborative idea generation is a frequently used approach in many settings. It is typically assumed that sharing ideas in groups will increase the number and novelty of ideas (Paulus, Dzindolet, Poletes, & Camacho, 1993; Sutton & Hargadon, 1996). However, studies that have compared collaborative ideation or brainstorming with the performance of similar numbers of individual performers (nominal groups) in various formats have typically found that interactive groups tend not to be better than nominal groups (cf., Paulus & Coskun, 2013). It has been suggested that alternating group and individual ideation may be a more optimal procedure than either alone or group ideation. However, research with this paradigm has been very limited thus far, and the results have been mixed. In a series of three experiments we examine more precisely than past research the variation in idea generation over the course of the alone and group alternation process in order to demonstrate the synergistic benefit of group ideation.

A review of traditional ideation methods shows that the benefits of group ideation depend on the type of paradigm used. In face-to-face (FTF) settings wherein ideas are shared verbally, groups typically generate fewer ideas than comparable size nominal groups, with the difference increasing with group size (Bouchard & Hare, 1970; Diehl & Stroebe, 1987). However, this performance deficit for groups can disappear when ideas are exchanged either electronically (electronic brainstorming-EBS) or by writing (brainwriting-BWr). These techniques help overcome the production blocking and evaluation apprehension that are some of the factors responsible for the low performance of FTF groups (Dennis & Williams, 2003; Heslin, 2009).

Although the EBS and BWr techniques appear to be useful for group ideation, their benefits are limited. EBS groups can typically outperform nominals only if groups

are size 8 or larger (Derosa, Smith, & Hantula, 2007). However, these effects are not large (Paulus, Kohn, & Arditti, 2011). Research has found that BWr groups can generate as many or more ideas than comparable nominal groups (Goldenberg, Larson, & Wiley, 2013; Paulus, Korde, Dickson, Carmeli, & Cohen-Meitar, 2015; Paulus & Yang, 2000). The positive effects of BWr appear to depend on the exact procedure used (Goldenberg, et al., 2013).

Even though EBS and BWr can eliminate the production losses observed in FTF brainstorming, it is apparent that the evidence for the synergistic effect of group collaboration using these paradigms is quite limited. A demonstration of synergy would require that the performance of the groups exceed those of the nominals (Larson, 2010). There are a number of potential reasons for this state of affairs. Sharing ideas in a group should be cognitively stimulating (Nijstad & Stroebe, 2006; Paulus & Brown, 2007). There is in fact evidence that exposure to the ideas of others can stimulate additional ideas because of associative processes (Dugosh, Paulus, Roland and Yang, 2000; Nijstad, Stroebe, & Lodewijckx, 2002) and the exposure to different categories of ideas (cf., Deuja, Kohn, Paulus, and Korde, 2014). However, the group exchange process can also slow down the rate of exchanging ideas. The efficiency of the group exchange process is limited by the task or coordination demands of this process (Steiner, 1972). This is most evident in the FTF case since group members have to take turns to present their ideas. Although turn taking is not required in EBS and BWr, the time spent reading ideas from others takes away from generating one's own ideas. Furthermore, although ideas from others can be stimulating, they can also distract from one's own train of thought or may

lead to free riding (Kerr & Bruun, 1983) in that one may feel less responsibility for generating ideas if others are generating many ideas.

One solution to this dilemma is to have individuals participate in both alone and group sessions. In fact, Osborn (1953) noted “an alternation between group ideation and individual ideation is desirable, since a combination of these two methods has produced maximum results in almost every case.” (p.209). Although Osborn provided no empirical data to support this claim, it seems reasonable to expect that combining individual and group brainstorming into a single paradigm or “hybrid brainstorming” may be an optimal procedure. This would allow both for unconstrained ideation in individual brainstorming and stimulation of additional ideas by exposure to ideas of others. This might be most evident with the EBS and BWr paradigms since these significantly reduce production blocking.

There has been very limited work on brainstorming procedures that combine the individual and group paradigms. Some studies have varied the order of alone and group brainstorming to determine which order is most beneficial. One might expect that group brainstorming would be most beneficial after a period of individual brainstorming. This allows participants to generate their ideas in an unconstrained fashion first, and then when thinking of new ideas becomes more difficult, group interaction may provide cues to additional ideas or categories of ideas. One study has in fact found that this order is most beneficial (cf., Baruah & Paulus, 2008). However, one can also argue that having group interaction before a solitary ideation session would be beneficial since this provides participants a chance to reflect on the shared ideas and build on them while the shared ideas are still salient in the associative network (Brown & Paulus, 2002). Evidence

for the superiority of this order has been obtained in two studies using BWr (Paulus & Yang, 2000; Paulus, et al, 2015) and also in several studies with verbal brainstorming (Dunnette, Campbell, and Jastad, 1963; Leggett, Putman, Roland, & Paulus, 1996). One of the more famous examples of this type of effect is Einstein's writing of the theory of relativity. After a long discussion session with his friends on this topic, he isolated himself in a room to write out the basics of his theory (Denis, 1996).

Given the different findings on the effect of the order of alone and group brainstorming and the fact that some studies find no effect of order (Paulus, Larey & Ortega, 1995; Rotter & Portugal, 1969; Taylor, Berry, & Block, 1958), it would seem that the most important consideration might be simply the importance of alternating alone and group brainstorming rather than focusing on the benefits of one particular order.

However, only a small number of studies have assessed this possibility and each of these have methodological limitations. A number of studies used different procedures for generating ideas in different conditions. Rotter and Portugal (1969) compared nominal and interactive groups with those that worked both alone and as a group (in two different orders). All of the participants wrote their ideas on a sheet of paper. The participants in the alone condition performed best, with the alternating condition leading to better performance than the group condition. However, the alone sessions were done only with writing whereas the group session also involved discussion of the written ideas that took time away from idea generation. Several EBS studies have used a form of asynchronous brainstorming group in which members submit their ideas at different points in time. That is, ideas are submitted individually but to a central location or forum that is accessible to all members of the group. This paradigm should allow group members to follow their

train of thought without being disrupted, while also being able to gain stimulation from other members' ideas. Dornburg, Stevens, Hendrickson and Davidson (2009) examined asynchronous brainstorming over the course of four days using a large EBS group that was compared to individual brainstorming. There was no difference in the number of ideas generated between the individuals and the group. Individuals outperformed the group in originality, feasibility and effectiveness. But the duration of brainstorming was not controlled, and the study only involved one interactive group of 30. Ocker, Fjermestad, Hiltz, & Johnson (1998) compared FTF brainstorming with two different types of EBS procedures (synchronous and asynchronous) and a combination group. However, the synchronous groups worked at the same time in the same room, while members of the asynchronous groups worked from different locations at different times. In the combination group, participants first worked FTF and later worked asynchronously. All groups received two weeks to work on the given task. The amount of time allowed for communication among group members in the asynchronous conditions was not controlled. The combined groups generated significantly more creative solutions and a better quality solution than the asynchronous, the synchronous, and the FTF groups.

Some studies did not have alone or nominal control conditions, Girotra, Terwiesch, and Ulrich (2010) compared a "hybrid" condition to a group condition. Participants in the hybrid condition were asked to write their ideas individually for the first ten minutes and then share and discuss the ideas as a group (FTF) for the remaining time. Participants using the hybrid process generated three times more ideas than those in the real groups. Since the hybrid condition used both BWr and FTF techniques, while the

real group only used FTF, it is possible that the benefit of the hybrid condition may simply be due to a difference in techniques across conditions.

De Vreede, Briggs, and Reiter-Palmon (2010) examined the asynchronous brainstorming process using multiple groups. Large EBS groups were comprised of subgroups that either completed the entire brainstorming process on their own (parallel mode) or built on the work provided by the previous subgroups (serial mode). They found that serial processing was better suited for tasks that require in-depth processing and elaboration, but parallel processing was appropriate for tasks that demand multiple new ideas. However, there was no individual control group to determine the relative effectiveness of group interaction.

Although there is evidence that using a hybrid procedure may have some benefit over traditional group brainstorming, the results are not clear because of lack of control groups and lack of comparability of procedures. In the present series of experiments the same technique (BWr) was used in all conditions. Alone and group BWr conditions were compared to hybrid conditions that alternated alone and group brainstorming sessions. This design allowed us to determine to what extent the alternating process enhanced the number of ideas relative to the alone and group conditions. Eight-minute sessions were employed since prior unpublished research has suggested that benefits of hybrid brainstorming can be observed with this type of timing (Korde, 2012). BWr was used since we felt that this procedure was more likely than the FTF and EBS ones to demonstrate a benefit of the hybrid procedure because of the more efficient group exchange process. There are several demonstrations of such small BWr groups exceeding the performance of nominal groups (Paulus et al., 2015; Paulus & Yang, 2000). However,

small EBS groups of size less than 8 tend to show production losses relative to same size nominal groups. These differences in outcome for EBS and BWr groups may be due to that fact that a collaborative stimulation effect can occur only if participants pay attention to the shared ideas (Dugosh, et al., 2000; Paulus & Yang, 2000). In the typical EBS programs there is no way to be sure that participants are reading all the ideas presented to them. In the BWr procedure used in the present experiments, reading shared ideas is part of the process. Recent research has shown that BWr can produce more ideas than EBS when participants are forced to make an effort to read the ideas (Michinov, 2012). However, there has to be reasonable balance between time spent reading others ideas and generating one's own ideas (Paulus & Brown, 2002).

It is expected that hybrid brainstorming will be more effective than both group and alone brainstorming, but this could occur for a variety of reasons. There are least two theoretical perspectives, which suggest that individual ideation will be elevated after group ideation. The cognitive models suggest that the cognitive stimulation from group ideation sessions can yield associations that can be the basis for enhanced idea generation in a subsequent solitary ideation session. In fact, Brown and Paulus (2002) reported simulations based on their cognitive matrix model (cf., Brown, Tumeo, Larey, & Paulus, 1998) that demonstrated spikes in performance in an alone phase that followed a group phase. A production blocking/constraint perspective suggests that performance in a group session will be inhibited because the time taken to attend to others' ideas will take away from one's own idea generation time. But, in the alone session performance is no longer constrained by this demand, and this may provide some extra motivation to take advantage of this new freedom to generate ideas at will (Amabile, 1996). We are not

aware of any demonstrations of such effects, but there is a literature suggesting that various cognitive and task constraints can motivate individual creative behavior (Medeiros, Partlow & Mumford, 2014; Stokes, 2005). However, this research has not addressed the possible positive effects of eliminating the constraint on subsequent creativity.

In contrast to the above discussion, a social comparison perspective suggests that the performance in the alone phases may be critical for enhancing performance in the subsequent group phases (Paulus & Dzindolet, 1993). The typically higher rate of performance in the alone session may become a reference point for participants in a subsequent group session and result in an elevated level of performance relative to a condition in which participants share ideas only as a group. Paulus and Dzindolet (1993) found that performance in subsequent sessions is positively correlated with the performance rate in earlier sessions (Studies 3 & 4). Thus those who started with a task that yielded a higher rate of idea generation performed better on a subsequent different idea generation task than participants who started off with a lower rate task. This type of pace entrainment effect was stronger for group ideation than individual ideation, consistent with the entrainment perspective of Kelly (1988) as well as a social comparison perspective. Thus according to a social comparison perspective, a preliminary alone session may enhance the performance of a subsequent group session and this pattern may be entrained during the sessions that follow.

In a preliminary experiment we examined the potential benefits of hybrid ideation and the impact of starting a session with alone or group ideation (see Korde, 2014 and supplementary materials for details). The experiment employed a brainwriting paradigm

for four eight-minute sessions, either all alone or in an alone-group-alone-group (AGAG) or a group-alone-group-alone (GAGA) sequence. It was found that the AGAG sequence led to more ideas than the other two conditions. The performance in the alone phases was elevated relative to the other phases, but only the second alone phase in the AGAG condition was significantly different from same phase in the alone condition. Thus this study provides some support for the perspectives which suggest that the benefit of hybrid ideation will be primarily due to enhancement of performance in the alone phases. However, a possible sampling bias in the AGAG condition and the fact that hybrid condition participants received additional training may have influenced the results. Thus we conducted two similar experiments to more definitively assess the effects of hybrid ideation.

Experiment 1

Experiment 1 included the three conditions of the preliminary study and a group condition, with four phases in each condition. Participants either switched back and forth from group brainstorming to working alone or generated ideas alone or as a group for the entire session. There were two hybrid conditions depending on which phase was first – alone or group. The four conditions were 1) alone-group-alone-group (AGAG) 2) group-alone-group-alone (GAGA), 3) alone-alone-alone-alone (Alone) and 4) group-group-group-group. Each phase (alone or group) within the conditions lasted for eight minutes and the total brainstorming session for each condition was 32 minutes long. In all the conditions, participants performed in groups of three. However, in the alone condition they performed the task individually but in the presence of other members of their group.

Based on previously discussed research and theory, the hybrid conditions should lead to more ideas than the nominal and group conditions.

H1. Participants in the hybrid conditions will generate more ideas than those in the alone and group conditions.

Prior research might lead one to expect differences between the two different hybrid conditions. Given the findings that either sequence can be beneficial, there is not a strong empirical basis for making a differential prediction. However, both the cognitive and blocking/constraint perspectives suggest that a condition that begins with a group session may have an advantage. However, the social comparison and entrainment perspectives suggest that the condition that begins with an alone session will lead to the better performance. Furthermore, the cognitive and blocking/constraint perspectives both suggest that the alone sessions that follow the group sessions will demonstrate elevations in performance in comparison to the alone condition. In contrast the social comparison and entrainment perspectives suggest that a group session that follows an alone session will be elevated relative to the group condition.

H2a. In accord with the cognitive and blocking/constraint perspectives, the hybrid condition that begins with a group session will lead to a better performance than one that begins with an alone session since group sessions should be followed by elevations in the performance during alone sessions.

H2b. In line with the social comparison and entrainment perspectives the hybrid condition that begins with an alone session should lead to the best performance since this will lead to elevations in the performance in the subsequent phases and elevations in performance the group sessions that follow the alone sessions.

H3a. In accord with the cognitive and constraint perspectives the alone sessions that follow group sessions in both of the hybrid conditions should show enhanced performance relative to the comparable phases in the alone condition.

H3b. In accord with the social comparison and entrainment perspectives the group sessions that follow an alone session in both of the hybrid conditions should show enhanced performance relative to the comparable phases in the group condition.

A blocking/constraint perspective would suggest that the more constrained the performance is in the group phase in terms of number of ideas, the greater will be the subsequent enhancement in the alone phase. This could be examined by examining the extent to which the performance in the first group phase of the hybrid condition is lower than the prior alone phase. The greater the discrepancy, the greater should be the experience of constraint and the subsequent increased motivation to perform in the alone session that follows the group session.

H4: If blocking/constraint plays a role in the elevation of the performance of the alone phases after the group phases in the hybrid condition, the performance in the second alone session will be positively related to the degree of constraint experienced in the group phase in comparison to the prior alone phase.

Studies that have used BWr techniques have obtained mixed results as to the benefit of sharing ideas in a group. Paulus and Yang (2000) and Coskun (2005) both found that real groups generated more ideas than nominal groups when the BWr technique was used. However, the nominal groups generated ideas on a single sheet of paper, and the interacting groups generated ideas on slips of paper. A study by Goldenberg, et al., (2013) found that when participants in the nominal condition are also

asked to write their ideas on separate slips of paper, the difference in number of ideas generated by the interacting groups and nominal groups disappears. Since the BWr technique involved separate slips in all conditions, it was anticipated that there would be no difference between the alone and group condition. However, Paulus et al. (2015) found that group BWr led to more ideas than alone writing for employees of a technology company when all participants used individual slips. This result was only marginally significant with the relatively small sample. Thus given the mixed findings in past studies, we did not make a directional prediction for alone and group brainwriting.

Method

Participants

Participants were undergraduate students from a large university in the Southwest U.S. who participated in the study in order to fulfill introductory psychology class requirements. 189 students participated in the study, and data from nine participants were not used as they failed to follow instructions correctly. Six of these participants belonged to the Alone condition and three to the Group condition. Participants were randomly assigned to one of the four experimental conditions, each consisting of 15 groups of three. Data from 45 individual participants were pooled together to create 15 nominal groups. In our previously published studies on brainwriting, we have found effects related to alone and group sequence with 10 or 12 groups per condition (Paulus et al., 2015; Paulus & Yang, 2000). All data were collected prior to our analyses. The average age of the participants was 20.16 years ($SD = 3.45$). There were 110 females and 70 males.

Design and Procedure

The experiment used a 4 (Condition) X 4 (Phases) mixed design. Informed consent was obtained from the participants before providing them with the instruction packet. Participants were provided instructions about the task, the rules of brainstorming (Osborn, 1957), and the procedure to be used. All the participants wrote their ideas on colored slips of paper and were instructed to write only one idea per slip. Each participant received a different set of colored slips (pink, white, or yellow). In the group phases, participants were seated at a table, facing each other and were asked to pass the ideas to the person on their right and were told to read the ideas that they would receive from their left. Once the participants received their own ideas back, they were asked to place them at the center of the table. During the alone phases, participants were asked to write their ideas and simply place the slip of paper next to them without passing it on. At the end of each phase the slips were collected and placed into separate envelopes and labeled by group and phase. The participants were given different colors of pen for each phase. The colors of pens used were constant across condition and were always used in the same order (blue, red, purple, black) regardless of phase type (alone or group). Participants in all of the conditions were given a group practice session with the “alternate uses of a paper clip” topic, even though those in the Alone condition would be performing alone, to ensure that all conditions had similar training. For the brainstorming session, participants were asked to generate ideas to the “thumbs problem”— the implications of having an extra thumb on one’s hand. At the end of the session, participants completed a questionnaire about the task and their performance.

The number of non-redundant ideas for each phase was used as the dependent variable. This was the only performance measure obtained in this experiment. We also

obtained responses to a post-experimental questionnaire. This included items that asked participants to rate their performance in the different phases. However, since only the hybrid condition involved different phases, the items were not comparable across the conditions and thus were not analyzed. In the subsequent experiment, all of the measures obtained are also reported as well as any exclusion of participants.

Results

The data were analyzed at the group level using a 4 (Condition) X 4 (Phases) mixed ANOVA (refer to Table 1 for descriptive statistics). The results showed that there was a significant main effect of condition, $F(3, 58) = 2.854$, $p = .045$, $\eta_p^2 = .129$. Participants in the AGAG condition generated more ideas than those in the group condition, although this difference was marginally significant ($p = .056$). The other conditions were not significantly different from one another. Thus, there was only partial support for Hypothesis 1 and no support for Hypotheses 2a or 2b.. There was also a significant main effect of phases, $F(3, 174) = 99.365$, $p < .001$, $\eta_p^2 = .631$. Significantly more ideas were generated in Phase 1 across all conditions as compared to phases 2, 3 and 4 ($p < .001$). A significant interaction effect was also observed, $F(9, 174) = 13.008$, $p < .001$, $\eta_p^2 = .402$. This is primarily due to the elevation of the performance in the alone sessions of the hybrid conditions that followed the group sessions in support of Hypothesis 3a. (see Figure 1). Pairwise comparisons using the Bonferroni adjustment indicated that quantity was significantly higher in Phase 1 of the AGAG condition as compared to the GAGA (mean difference = 10.113, $SE = 3.247$, $p = .017$) and Group conditions (mean difference = 11.008, $SE = 3.247$, $p = .008$). For phase 2, the performance in the GAGA condition was significantly higher than the AGAG (mean difference = 8.804, $SE = 3.145$, $p = .042$)

and Group (mean difference = 12.312, $SE = 3.094$, $p = .001$) conditions. In phase 3, significantly more ideas were generated in the AGAG condition as compared to the GAGA (mean difference = 11.479, $SE = 3.417$, $p = .008$) and Group (mean difference = 12.729, $SE = 3.417$, $p = .003$) conditions. There were significantly more ideas in the phase 4 of the GAGA condition as compared to the same phase of the Group condition (mean difference = 10.938, $SE = 2.979$, $p = .003$). More ideas were generated in phase 3 of the AGAG condition as compared to the same phase of the Alone condition, but this difference was only marginally significant, $t(58) = 2.592$, $p = .072$. A specific planned comparison of the combined quantity in the alone phases (phases 2 and 4) of the GAGA condition was significantly higher than the combined quantity of the corresponding phases in the Alone condition $F(2, 58) = 4.860$, $p = .011$, $\eta_p^2 = .144$, in support of Hypothesis 3a. Contrary to the blocking/constraint perspective (H4), the extent to which performance was lower in the first group phase of the AGAG condition relative performance in the prior alone phase was negatively related to performance in the subsequent alone phase, $b = -.383$ (CI -.748, -.017), $SE = .169$, $t(13) = -2.261$, $p = .042$.

Discussion

As in the preliminary study, there was an elevation in performance during the alone phases that followed the group phases of the hybrid conditions. This pattern of results supports the prediction made on the basis the cognitive/associational models of collaborative ideation (Brown & Paulus, 2002; Nijstad & Stroebe, 2006). However, it could also reflect the enhancement of idea generation after constraint due to production blocking. As a result of the elevated performance during these phases the hybrid conditions performed better than the other two conditions, but these differences were not

statistically significant. The results did not support the social comparison perspective since there was not an elevation of performance in the group phases after the alone phases in the hybrid conditions in comparison to the comparable phases in the group condition.

The group condition did not generate significantly more ideas than the alone condition. This is consistent with the findings of Goldenberg, et al. (2013) who also found no differences in quantity when slips of paper were used to write the ideas instead of a single sheet of paper. This result may seem to indicate that generating ideas in a group has no benefit as compared to generating ideas individually. When participants are working in a group, their attention and time is divided between generating their own ideas and reading others' ideas. This may lead to distraction and some production loss (Santanen, Briggs, & de Vreede, 2004; Valacich, Dennis, & Connolly, 1994). In fact, in the first alone phase of the AGAG condition was significantly higher than the first group phases in the Group and GAGA condition. However, this result does not necessarily indicate a lack of stimulation in the group phases. The effect of stimulation from group ideation can be seen more clearly when comparing within the conditions rather than across the conditions. For the hybrid conditions, the data clearly show an increase in ideas in the alone phases after the group phases, whereas the number of ideas in the nominal condition does not increase at any point during the session. Thus, this may reflect the benefit of group stimulation (Dugosh et al., 2000; Paulus & Brown, 2007; Paulus & Yang, 2000) and this benefit is only visible after the group phase. The key is to allow the participants to work individually after a group phase so that they may utilize the group derived stimulation more effectively.

Another interesting finding from Experiment 1 is that the number of ideas generated by participants in the alone condition drops considerably from phase 1 to phase 2. But after phase 2, the rate of idea generation stays almost constant until the end. Prior research with verbal brainstorming has found a more consistent decline in the performance of the alone participants over time so that the difference in quantity of ideas between the nominal and interacting groups almost disappears (Paulus & Dzindolet, 1993, Experiment 5). More of a decline in the number of ideas was expected from the nominals in Experiment 1 because they received no ideas from other participants in the 32-minute long session. It is possible that participants continued to generate ideas due to the motivating effects of the social cues present. When participants generated ideas and kept the slips to their side, the stacks of slips (but not the ideas) were visible to the other participants. Previous research has shown that this social comparison of performance can lead to an increase in the number of ideas generated (Dugosh & Paulus, 2005; Paulus, Larey, Putman, Leggett, & Roland, 1996). If these participants were generating ideas without the social cues (i.e., without being able to see each other), their rate of ideation may have shown a steeper drop. If that is true, the decline should be evident in all of the alone phases regardless of condition – alone or hybrid. Isolating the group members for this phase in the hybrid condition may help determine if the previously seen increase in quantity of the alone phases that followed the group phase was purely due to stimulation they received from the group phase or was influenced by the effect of social cues from the alone phase. If participants in the hybrid condition are able to utilize the stimulation from the group phase, quantity in the alone phases of the AGAG condition should not drop as drastically as it might in the alone condition.

The hybrid condition was designed to mimic the way in which ideation often occurs in the real world. Group meetings can occur a few times a week with time in between for individuals to generate more ideas and discuss them at the next meeting and so on. However, these individual brainstorming phases occur when the individual is away from other group members. The individual phases in Experiment 1 occurred in full view of the other group members. Therefore, it may be instructive to examine the effect of the hybrid condition when the group members are separated or unable to view each other's performance during the alone phases.

In Experiment 2 social cues were eliminated in the alone condition and alone phases of the hybrid condition, and we added another eight-minute phase to lengthen the session to enhance the chances of seeing a decline in the alone condition. This could result in the group condition matching or exceeding the performance of the alone condition since alone participants could begin to run out of ideas without external stimulation (Dennis et al., 2005; Nijstad, Stroebe & Lodewijkx, 1999). In Experiment 1 we only measured the number of ideas generated since that has been the main measure of choice in this type of research. However, in the second experiment we added additional performance measures to obtain a richer set of data on the effects of hybrid brainwriting and to allow for discrimination between the cognitive and blocking/constraint perspectives.

Experiment 2

Experiment 2 compared a hybrid and a group condition to an alone condition, and group members were isolated in the alone condition as well as all alone phases. The

overall procedure remained similar to the prior two experiments. The session time was increased from 32 minutes to 40 minutes by adding a fifth phase.

To prevent the participants from seeing each other, partitions were placed between participants during all the individual phases, across all the conditions. So only the group phases occurred in full view of all the group members without the partition. Since the participants would be isolated during the individual phases to eliminate both cognitive and social cues, it was expected that fewer ideas would be generated in the alone condition as compared to the hybrid condition. The hybrid condition would receive some stimulation from the group phases, whereas the alone condition would not.

The first two hypotheses are similar to those of the prior experiments.

H1. More ideas will be generated in the hybrid condition as compared to the alone and group conditions.

H2. The alone phases that come after the group exchange in the hybrid condition will demonstrate an elevated level of idea generation compared to the same phases in the alone condition.

For this experiment we also developed hypotheses for the additional measures of the novelty of ideas, their variety, and the depth of categories explored. The number of categories (variety) is often but not necessarily correlated with number of ideas (Deuja et al., 2014), average novelty is typically fairly independent of the number of ideas (Paulus, et al., 2011), but depth of categories (number of ideas per category) can be related both to enhanced novelty and quantity (cf., Nijstad, De Dreu, Rietzschel, & Baas, 2010; Rietzschel, Nijstad & Stroebe, 2007). For example, a number of studies have found that a focusing on one category at a time as an individual or a group enhances the number of

ideas generated (Baruah & Paulus, 2011; Coskun, Paulus, Brown, & Sherwood, 2000; Deuja et al., 2014).

The dual pathway model of De Nijstad et al. (2010) suggests that ideational creativity (novelty) involves both persistence (category depth) and flexibility (category variety) pathways¹. Both persistence and flexibility are important when generating ideas in a group. Since the hybrid condition has both individual and group phases, these factors become important in understanding cognitive processes involved in the hybrid condition. Persistence, that is, focusing on a category and digging deeper may be more feasible when working alone. The stimulation from shared ideas when working in a group should increase the flexibility or number of categories explored in the subsequent alone phases. Prior, research has typically found that as the number of ideas generated increases so do the number of categories (e.g., Kohn & Smith, 2010). Based on the results from Experiment 1, the De Dreu et al. (2012) findings, and the Nijstad et al. (2010) dual pathway model, the following hypotheses are proposed:

H3. The hybrid condition should demonstrate enhanced depth and variety because of the benefit of both group stimulation and private reflection time.

H4. The hybrid condition will have the highest novelty since participants should be able to utilize both flexibility and persistence pathways.

¹ De Dreu, Nijstad, Baas, Wolsink & Roskes (2012) assessed these relationships using individual brainstorming and the role of working memory. In experiment 3, the effects of working memory capacity were tested on the alone, group, and hybrid conditions. Working memory was assessed using three different measures – OSPAN, RSPAN and WCST. Several mediation models and moderated regression analyses were conducted to examine the effects based on the dual pathway model. The results showed that only lower scores on OSPAN (lower working memory capacity) significantly predicted higher novelty in the hybrid condition via the flexibility pathway. Scores on personality variables like openness to experience, extraversion, and perspective taking also did not have significant effects on quantity, variety depth, or novelty (See Korde, 2014).

The exposure to the ideas of others in the group phase of the hybrid condition should increase the awareness of a broader range of categories and increase the extent to which participants generate ideas in a broader range of categories in the subsequent alone phase.

H5: The alone phases that follow the group sessions in the hybrid condition will show more category variety (flexibility) than the corresponding phases of the alone condition.

The generation of ideas is also related to the extent to which to which categories are tapped more deeply (Baruah & Paulus, 2011; Deuja et al., 2014).

H6a. We expect that the ideas in the alone phases that follow group sessions in the hybrid conditions will demonstrate greater depth than the same phases in the alone condition.

Persistence or focusing on a category and digging deeper may be more feasible when working alone since the train of thought is not disrupted by exposure to the ideas of others.

H6b. The alone phases will show more category depth than the group phases, regardless of condition.

We will also analyze the extent to which the performance in one phase predicts performance in a subsequent phase. For the alone condition intersession correlations should primarily reflect individual differences in ability or motivation. These factors also should play a role in the other conditions. However, in the group condition the tendency for social comparison and normative influence may lead to even stronger correlations among the sessions as in the Paulus and Dzindolet (1993) study. In the hybrid conditions,

the correlations may be somewhat lower since the contiguous sessions involve a change in the ideation process. Of primary interest will be the patterns in the hybrid condition and their theoretical implications. We would expect the quantity, variety, depth and novelty of the group phase to influence the same measures in the alone phase because of related cognitive stimulation and the carry-over of social influence and entrainment effects from one phase to the other. If the enhanced performance in the alone phases that follow group phases were due to various cognitive processes, one would expect a number of other relationships. The greater the variety of categories (flexibility) experienced in the group phase, the better should be the performance in the alone phases because the categories can prime new semantic domains (e.g., Coskun, Paulus, Brown, & Sherwood, 2000). The greater category depth in the group phase may increase the novelty of the ideas in the subsequent alone phase as well the number of ideas. Category depth has been associated increased novelty in alone and dyadic conditions (Nijstad, et al. Baas, 2010; Rietzschel et al., 2007). However, category depth has also been associated with an increase in the number of ideas generated since focusing on one idea at a time is an efficient cognitive strategy (Deuja et al., 2014). The novelty of ideas in the group phase may not enhance the number of ideas generated in the subsequent alone session since more common ideas may yield more associations (Dugosh & Paulus, 2005).

H7: The performance in the alone phases after the group phases will be predicted by the quantity, variety and depth of ideas in the prior group phases.

The blocking/constraint perspective is not well suited for making predictions about the different measures of performance since it involves a non-specific motivational process. However, as suggested for Experiment 1, the degree of constraint experienced in

the first group phase of AGAG condition could be related to enhanced performance in the following group phase. This did not occur in Experiment 1, but we again assessed this possibility in Experiment 2.

H8: If blocking/constraint plays a role, the performance in the second alone session will be positively related to the degree of constraint experienced in the group phase in comparison to the prior alone phase.

Method

Participants

Participants were recruited from a large university in the Southwestern U.S. and all participants received research credits to help complete requirements for their courses. If a complete group of three students arrived for the session, they were randomly assigned to either the group or hybrid brainstorming conditions. If fewer than three people arrived for the session, they were automatically assigned to the individual brainstorming condition. Data from three individual participants were pooled together to form a nominal group. A total of 270 students participated in the idea generation and data from all the participants were used for the analyses. The number of groups per condition was doubled in number compared to Experiment 1 since we anticipated needing additional power for planned path analyses. All of the data were gathered before the analyses of the data were begun. The mean age was 20.03 ($SD = 3.664$); the youngest participant was 17 and the oldest was 62 years of age. 54.1% of the sample consisted of females. 30% of the sample was Hispanic, 28.5% were Caucasian, 21.1% Asian, 15.2% African American, and the remaining one percent comprised of Native Americans,

Pacific Islanders and those who reported more than one race. Only one participant did not disclose their race.

Design and Procedure

The experiment used a 3 (Condition) X 5 (Phases) mixed design. Participants were recruited to come to the lab in groups of three to complete the brainstorming task. Similar to the prior experiments, brainwriting was the procedure of choice and slips of paper were used to write ideas. Each participant received a different set of colored slips (pink, white, or yellow) to easily identify as their own. The ideas were written using a different colored pen for each phase (blue, red, purple, black, and orange). Participants in all the conditions received a three-minute group practice session and topic was “alternate uses of a paper clip”. The thumbs problem was used again for the brainstorming task. Participants sat at a table, facing each other. A partition was placed between those participants that were starting the first phase individually. Those in the alone condition continued the remaining phases with the partitions in place, stopping every eight minutes for a change of pens. Each phase lasted for eight minutes just as the previous experiments. The partition was removed for the participants in the hybrid condition just before every group phase. All the phases for the group condition took place without the partition. At the end of the session the participants were asked to complete a post-experiment questionnaire and were debriefed.

Dependent Variables

The dependent variables obtained for this experiment were quantity, novelty, category depth, and category variety of the ideas. The scores on all of these variables

were calculated for each phase within each group. The operational definitions of these variables are as follows:

- Quantity: Total number of non-redundant ideas. Ideas that were repeated across phases and within a phase were considered as redundant and were not counted. Ideas were counted and checked for redundancy by two trained raters. Both raters counted all the ideas for all the sessions and removed redundant ideas by consensus.
- Novelty: Novelty was determined based on the infrequency of the ideas. Ideas that were produced frequently by many participants were considered less novel. Whereas ideas that were rarely produced by participants were rated as novel. Two trained raters rated novelty of the ideas independently. The ideas were rated on a scale of 1 to 5, where one meant “very common” and five stood for “very uncommon”.
- Category variety (Flexibility): Ideas were also sorted into different categories. Using previous data, 24 categories were developed for the thumbs problem (Korde, 2014). Some of those categories were social/discrimination, sports, gestures, etc. The total number of categories explored by each participant and by the group was recorded.
- Category depth (Persistence): For each category that was explored by a participant, the total number of ideas generated within that category and the average number of ideas per category was calculated by dividing quantity for the phase by the corresponding category variety score. An overall category depth score was also calculated for each group.

As in the case of Experiment 1, the questionnaire responses were not analyzed since the items were not designed to tap the processes relevant to the hybrid condition.

Coding of Ideas

Data from the brainstorming session were screened to eliminate redundant ideas by consensus. The ideas were coded for novelty and categories by two independent raters. Both raters coded the ideas blind to the conditions and phases. Each rater coded 25% of the ideas for novelty on a scale of one to five as described earlier. Scores that were within one point of each other were considered as indicators of inter-rater agreement and the ratings were adjusted for analysis (Diehl & Stroebe, 1991; Kohn, Paulus, & Choi, 2011). Inter-rater reliability for the novelty ratings on 25% of the data was calculated using ICCs resulting in a value of .834. One rater then coded the remainder of the data for novelty.

Both raters also coded 25% of the data for categories. The raters independently assigned one of 24 categories to each idea. Cohen's Kappa was used to test inter-rater reliability and the resulting value was .808. The second rater coded the remaining 75% of data for categories. To calculate category variety, the number of non-redundant categories explored within each phase was counted. Additionally, the number of non-redundant categories explored throughout the entire session was counted. Therefore, each group had six separate category variety scores – one for each phase and one overall for the entire session. Category depth was computed by dividing the number of non-redundant ideas by category variety for the corresponding phase and/or session.

Results

The data were analyzed at the group level. Examination of the correlations among the variables for the three conditions combined showed that all four measures were significantly correlated with one another. Quantity was significantly correlated with the remaining three measures (variety: .509, $p < .001$; depth: .957, $p < .001$; novelty: .494, $p < .001$). Variety was significantly correlated with depth (.251, $p = .017$) and novelty (.407, $p < .001$), and depth was significantly correlated with novelty (.427, $p < .001$). Even though quantity and depth were highly correlated, given their distinct theoretical implications, we included both of these measures in our various analyses.

Quantity

Four separate 3 (Condition) x 5 (Phases) mixed ANOVAs were used to test the differences among conditions and phases on each of the four dependent variables – quantity, novelty, category variety, and category depth (refer to Table 2 for descriptive statistics). The ANOVA for quantity yielded a significant main effect of condition, $F(2, 87) = 3.430$, $p = .037$, $\eta_p^2 = .073$. Pairwise comparisons using the Bonferroni adjustment indicated that the hybrid condition had the highest mean number of ideas ($M = 37.407$, $SE = 1.962$), followed by the alone condition ($M = 34.980$, $SE = 1.962$), and then the group condition ($M = 30.260$, $SE = 1.962$). However, the hybrid condition was only significantly different from the group condition, $p = .035$. The other differences between conditions were not significant. Hypothesis 1 was only partially supported. There was also a main effect of phases, $F(4, 348) = 86.179$, $p < .001$, $\eta_p^2 = .498$. As expected, the most ideas were generated in the first phase and quantity declined as the phases progressed. Phase 1 was significantly different than all the other phases ($p < .001$). The interaction between condition and phase was also significant, $F(8, 348) = 8.829$, $p < .001$,

$\eta_p^2 = .169$ (see Figure 2). Significantly more ideas were generated in the AGAG condition as compared to the Group condition in phase 1 (mean difference = 9.433, $SE = 3.000$, $p = .007$), phase 3 (mean difference = 11.500, $SE = 2.964$, $p = .001$) and phase 5 (mean difference = 12.067, $SE = 3.423$, $p = .002$). The within condition comparisons showed enhanced performance in the alone phases after the group phases in the hybrid condition (see Figure 2). The combined quantity of phase 3 and phase 5 was significantly higher in the hybrid condition than the alone condition, $F(1, 87) = 4.590$, $p = .035$, $\eta_p^2 = .050$. These results support hypothesis 2. Quantity in the Group condition was highest in phase 1 (phase 2: mean difference = 6.033, $SE = 1.297$, $p < .001$; phase 3: mean difference = 9.033, $SE = 1.360$, $p < .001$; phase 4: mean difference = 8.800, $SE = 1.547$, $p < .001$; phase 5: mean difference = 12.167, $SE = 1.749$, $p < .001$). Quantity in phase 2 was also significantly higher than the quantity in phase 5 (mean difference = 6.133, $SE = 1.609$, $p = .003$).

Categories

Testing for differences in the number of categories explored or category variety yielded a main effect of condition, $F(2, 87) = 7.849$, $p = .001$, $\eta_p^2 = .153$. The group condition explored fewer categories than the alone (mean difference = -1.413, $SE = .466$, $p = .010$) and hybrid conditions (mean difference = -1.733, $SE = .466$, $p = .001$). However, since the alone and hybrid conditions did not differ significantly from each other, there was only partial support for Hypothesis 3. There was a main effect of phases, $F(4, 348) = 19.641$, $p < .001$, $\eta_p^2 = .184$; category variety decreased from phase 1 to phase 5. Variety in phase 1 was significantly higher than variety in the remaining phases (phase 2: $p = .003$; phase 3, 4, and 5: $p < .001$). The interaction effect of conditions and

phases was significant, $F(8, 348) = 2.846, p = .004, \eta_p^2 = .061$ in support of Hypothesis 5 (see Figure 3). Even though category variety declined over time, the pattern was different in the hybrid condition as compared to the alone and group conditions (see Fig. 3). There was a sharp increase in category variety for the hybrid condition in the third and fifth phase. These were the individual brainstorming sessions that occurred right after group brainstorming suggesting that they were exposed to newer or more categories during the group session. The dependent t -test yielded a significant difference among these phases, $t(29) = 4.050, p < .001$. Combined variety from phase 3 and phase 5 was significantly higher in the hybrid condition than the alone condition, $F(1, 87) = 4.697, p = .033, \eta_p^2 = .051$, in support of Hypothesis 5.

Category depth

The analysis for category depth revealed no main effect of condition, $F(2, 87) = .790, p = .457, \eta_p^2 = .018$, contrary to Hypothesis 3. However, there was a main effect of phases, $F(4, 348) = 20.668, p < .001, \eta_p^2 = .192$. The category depth decreased from one phase to the next as the session progressed. Category depth in phase 1 was significantly higher than category depth in all the other phases ($p < .001$). The other differences were not significant. The interaction between phase and condition on category depth was significant, $F(8, 348) = 3.201, p = .002, \eta_p^2 = .069$ (see Figure 4).

Similar to the pattern of interaction seen for category variety and consistent with Hypothesis 6a, category depth increased in phase 3 and phase 5 of the hybrid condition, after the group brainstorming phase. However, a planned contrast of the combined depth in phase 3 and phase 5 showed that those phases in the hybrid condition were not

significantly different from those in the alone condition, $F(1, 87) = 1.709, p = .195, \eta_p^2 = .019$.

It was also suggested that category depth could be greater in the alone phases as compared to the group phases, regardless of condition (H6b). Two t -tests were used to test this hypothesis – one independent t -test and one dependent t -test. The independent t -test compared the alone condition to the group condition, while the dependent t -test compared the alone phases to group phases within the hybrid condition. The independent t -test showed that there was no significant difference in category depth between the alone and group conditions, $t(58) = 1.228, p = .224$. The dependent t -test for the hybrid condition showed that the alone phases had significantly higher category depth than the group phases, $t(29) = 5.776, p < .001$. Therefore, hypothesis 6b was partially supported. Category depth was higher in the alone phase, but only within the hybrid condition. Hypothesis 3 was also partially supported since the hybrid condition demonstrated significantly higher variety but not a significant increase in category depth as compared to the alone condition.

Novelty

An ANOVA tested for differences in novelty of the ideas across conditions and phases. There was no significant effect of condition, $F(2, 87) = .604, p = .549, \eta_p^2 = .014$. Thus hypothesis 4 was not supported. However, there was a main effect of phases, $F(4, 348) = 102.329, p < .001, \eta_p^2 = .540$. Novelty of the ideas increased as the session progressed, leading to highest novelty in the fourth and fifth phases. Novelty in phase 5 was significantly higher than novelty in phase 1 and phase 2 ($p < .001$), and phase 3 ($p = .001$). There was an interaction effect of condition and phase on novelty of the ideas, $F(8,$

348) = 3.972, $p < .001$, $\eta_p^2 = .084$ (see Table 2). In the first phase, participants in the alone condition generated ideas with significantly higher average novelty than participants in the group condition (mean difference = .163, $SE = .062$, $p = .032$). By the fifth phase, the hybrid and group conditions showed higher novelty than the alone condition, consistent with findings of Baruah and Paulus (2016). However, the comparison was not significant (hybrid – $p = .176$; group – $p = .450$). None of the other comparisons were significant.

Mediation Model

It was expected that the hybrid condition would have the highest novelty since participants would be able to use both flexibility and persistence (H4). Based on the previously discussed results of the ANOVA, there was no significant main effect of condition on novelty. Even so, the mediation model was examined to test the second part of the hypothesis. Since the independent variable (condition) was a categorical variable with three levels, two dummy codes ($k-1$) were created and the alone condition was used as a reference group (Hayes and Preacher, 2014). The first dummy code (d_1) indicated the hybrid condition and the second (d_2) indicated the group condition. Category depth and variety were centered on the mean before they were added to the model. The “create a new estimand” command in AMOS was used to produce each of the specific indirect effects and the total indirect effect for each dummy coded condition. The chi-square for the base model (Figure 5) was significant, $\chi^2 (3) = 12.846$, $p = .005$. The GFI (.947) and AGFI (.735) were below the cut off, as was the CFI (.856). The RMSEA was .192 (CI : .093, .305) and significantly different than zero ($p = .013$). Based on these values the base model was not considered a good fit to the data. The modification indices suggested that

a path was needed from d_2 to novelty, i.e. the direct effect of the group condition on novelty. Theoretically, condition can predict novelty; but there is no reason to expect that only the group condition should have an effect on novelty. A second model was tested after adding direct paths from both indicator variables for the condition to novelty, and the chi-square was still significant, $\chi^2(1) = 3.927, p = .048$ (Figure 6). The GFI (.983) was above the cut off, but the AGFI was not (.745). The CFI (.957) was above the cut off but the RMSEA (.181, *CI*: .016, .384) was marginally significant ($p = .073$). The results showed that both models were not a very good fit, but the second model had slight better values based on the fit indices. Additionally, the AIC of the second model with the direct paths was lower (31.927) than the AIC of the base model (36.846). Therefore, parameter estimates were examined from the second model. Category depth ($b = .050, CI: .026, .068, SE = .010, p = .001$) and category variety ($b = .057, CI: .037, .081, SE = .011, p < .001$) both predicted novelty significantly. The a paths, total paths, direct paths, and indirect paths are described separately for each indicator variable.

Hybrid condition. The hybrid condition did not significantly predict category depth ($b = .535, CI: -.594, 1.609, SE = .561, p = .348$) or variety ($b = .133, CI: -.724, 1.110, SE = .470, p = .774$). The relative total effect of the hybrid condition on novelty was not significant ($b = .049, CI: -.090, .207, SE = .076, p = .482$), but it was in the expected direction. A one-unit increase (in this case from the alone condition to the hybrid condition) was related to an increase in novelty but the relationship was not significant. The relative direct effect ($b = .015, CI: -.103, .170, SE = .069, p = .784$) was also not significant. The relative specific indirect effects of the hybrid condition (via depth: $b = .027, CI: -.027, .088, SE = .028, p = .297$; via category: $b = .008, CI: -.047,$

.061, $SE = .027$, $p = .761$) and the relative total indirect effect were also not significant ($b = .034$, $CI: -.053, .122$, $SE = .044$, $p = .432$). The results did not support the 9th hypothesis – the hybrid condition did not significantly predict novelty via the persistence and flexibility pathways.

Group condition. The group did not significantly predict category depth ($b = -.731$, $CI: -1.947, .435$, $SE = .602$, $p = .220$), but it did predict category variety ($b = -1.033$, $CI: -2.014, -.012$, $SE = .515$, $p = .048$). The relative total effect was not significant ($b = .085$, $CI: -.048, .221$, $SE = .068$, $p = .203$) but the relative direct effect was significant ($b = .181$, $CI: .079, .291$, $SE = .053$, $p < .001$). A one-unit change (from the alone condition to the group condition) significantly predicted higher novelty when controlling for category depth and category variety. The relative specific indirect effect via depth was not significant ($b = -.036$, $CI: -.112, .017$, $SE = .032$, $p = .184$), but it was significant via variety ($b = -.059$, $CI: -.128, -.003$, $SE = .031$, $p = .039$). The relative total indirect effect was also significant ($b = -.096$, $CI: -.192, -.004$, $SE = .048$, $p = .041$). As compared to the control condition, the group condition predicted novelty as a result of the negative effect of the group condition on category variety.

Additional Analyses

We also examined the within session correlations to determine whether there were unique patterns in the hybrid condition. Of particular interest is how various measures of performance in the second and fourth group phases predict the performance in the following alone sessions. These results are presented in Tables 3 and 4. In addition we performed regression analyses to determine the relation of the performance in the second and fourth sessions to the final session (Table 5). In general the correlations were the

strongest for the group condition. For the hybrid condition significant correlations and regression effects occurred primarily for the quantity and depth predictors of the four variables, providing partial support for Hypothesis 7.

To examine the potential impact of constraint, we regressed the difference between the first alone and group session in the hybrid condition on the performance in the third alone phase. The bigger the gap between performance in the alone and subsequent group phase (lower performance), the greater the number of ideas generated in the next phase, $b = .528$, $SE = .232$, $t = 2.273$, $p = .031$. This same comparison for the other two conditions was not significant (alone condition, $b = -.505$, $SE = .312$, $t = -1.616$, $p = .117$; group condition, $b = -.217$, $SE = .408$, $t = -.530$, $p = .600$). These results provide some evidence that the performance constraint experienced in the group phase of the hybrid condition motivated increased performance in the subsequent alone phase (Hypothesis 8).

Discussion

The results of Experiment 2 are consistent with those of Experiment 1. The hybrid condition was the best in terms of number of ideas but not significantly better than the alone condition. The main benefit in the hybrid condition appears in the alone phases after exposure to ideas of others. This pattern occurred for number of ideas, number of categories and depth of categories but was only significant for the within phase analyses in the case of the latter.

In terms of number of ideas generated, the hybrid condition was significantly better than the group condition in the experiments in which a group condition was employed. However, to demonstrate a synergistic benefit of hybrid ideation the hybrid

condition needs to perform better than the alone condition. The trends in the three experiments (including the preliminary study) were in support of such an outcome. A meta-analysis was conducted to examine the difference in the hybrid and alone conditions across the three experiments. The means and standard deviations were used to conduct the meta-analysis (Borenstein, Hedges, Higgins, & Rothstein, 2005). Across the three experiments the total sample size for the two conditions was 114. The fixed effects statistics revealed a significant mean effect of 0.402 ($SE = 0.187$, 95% $CI = 0.036/0.768$), $z = 2.154$, $p = 0.013$. The degree of heterogeneity was not significant, $Q(2) = 3.257$, $p = 0.196$, indicating that the data from the three experiments were similar to each other. Since the beneficial impact was most evident in the alone phases after group interaction, we also did a meta-analytic comparison across the three experiments for the performance in the third alone phase of the AGAG conditions versus the alone conditions. The fixed effect statistics showed a main effect of 0.6994 ($SE = 0.191$, 95% $CI = 0.326/1.072$), $z = 3.672$, $p = 0.0002$, providing strong support for the performance enhancement after group idea exchange. Thus a consistent pattern of results has been obtained across the three experiments in support of the hybrid ideation and its synergistic benefit relative to the alone condition.

The benefit of hybrid ideation and the elevated performance in the alone phases of the hybrid conditions are consistent with the predictions based on the association models of group ideation (Brown & Paulus, 2002; Nijstad & Stroebe, 2006). This perspective suggests that group ideation generates associations that can be the basis for the generation of additional ideas. Only some of these can be expressed in the group

session, so the alone session provides an opportunity for the “spreading activation” of the associations to influence the idea generation in the alone session.

The analyses of the relationships between the sessions within the three conditions indicated that the performance was most consistent over time for the group condition, with all four measures of performance in one phase predicting the performance on all four measures in the subsequent phase in most of the comparisons. This is consistent with the entrainment (Kelly, 1988; Kelly & Karau, 1993) and social influence perspective (Paulus & Dzindolet, 1993) in that performance becomes more consistent or normative over time in the social context than in solitary sessions. In the hybrid condition the quantity and depth measures in the group phases were the primary predictors of subsequent performance in the subsequent alone phases on all four measures. The number of ideas being shared and the extent to which people dig deeply into specific categories has been associated with increased creativity in groups in a number of studies (e.g., Dugosh & Paulus, 2005; Rietzschel, et al., 2007). It now appears that these factors also affect the ability to continue generating ideas in subsequent solitary sessions, in support of the cognitive models of group creativity (Nijstad & Stroebe, 2006; Paulus & Brown, 2007).

Our research was framed in part in relation to the dual process theory of creativity (Nijstad et al., 2010), and some of our findings were consistent that that theory, such as the correlations among flexibility, depth and novelty. However, the path models for the hybrid condition did not fit with this particular perspective for predicting novelty. The elevation in performance in the hybrid condition reflected both enhancement of flexibility and depth, but this effect does not require an explicit dual process of flexibility and

persistence. The semantic network model of Brown and Paulus (2002) has predicted this type of outcome based on a category transition matrix model (Brown, et al., 1998). Thus individuals in a group are exposed to ideas and categories of ideas, which will in turn influence the subsequent ideation process. In generating ideas there is a tendency to stick in the same category until it has been somewhat depleted before moving on to other categories. So this model predicts that group exposure can increase both divergent (flexibility) and convergent thinking (depth). This model has been supported in a number of simulations of existing data (Brown et al., 1998; Coskun et al., 2000), and several simulations found evidence of a strong spike in performance of an alone session that followed a group session, including an increase in the number of categories in comparison to an alone only condition (Brown & Paulus, 2002).

There was some support for the blocking constraint perspective in the hybrid condition as well. In contrast to the findings of Experiment 1, the more that the performance in the group phase was lower than that in the prior alone phase, the better was the performance in the alone phase that followed the group phase. These cases should have experienced the most sense of constraint, which may have increased the motivation level when they were again “free” in the third session. However, since the overall high performance of the second and fourth group phases was related to increased performance in the subsequent alone phases, constraint cannot be the sole factor. This pattern fits most clearly with the cognitive perspectives. However, our study was not designed a priori to clearly differentiate between the cognitive and constraint perspective. Additional research is required to evaluate the potential motivational effects of constraint in these types of paradigms. For example, the constraint effect might be observed even if

the consecutive phases involve different problems. The cognitive perspective would not predict any elevations in performance in this case.

Although we have found enhanced performance in the hybrid condition, the boundary conditions for this effect remain to be discovered. For example, how will it be affected by problems varying in difficulty? The “thumbs problem” and other problems like generating ideas to improve a university are almost unlimited in the ideas that can be generated. They also have many different categories or types of ideas. Thus, ideas from others can be quite beneficial in suggesting new avenues for ideation. However, in more constrained problems with limited realistic options (such as generating ideas for reduced energy consumption), the potential stimulating effect of sharing ideas with others may be less dramatic. However, since one may quickly run of ideas on such a task, having input from others may be even more important.

The length of the session may also influence the outcomes. As we indicated earlier, idea generation tends to slow down rather dramatically in a short period of time for most problems. Brief breaks appear to reduce the pace of this decline (Paulus, Nakui, Putman, & Brown, 2006). The alone sessions served not only as breaks for the constraints of the demanding group exchange process but also provided an opportunity for unrestrained expression of ideas. Although there is a theoretical basis for predicting the pattern we observed, there are no definitive theoretical bases for predicting the optimal length of the sessions. Shorter sessions may be too disruptive, but longer sessions may be too tiring. Having longer group sessions and shorter alone sessions may reduce the benefits of the group-to-alone carry-over effects. However, if the alone sessions are too

long relative to the group sessions, there may not be enough stimulation to have a strong impact on the alone sessions.

The hybrid effect has implications for collaborative creativity in real world settings. It suggests that some balance of alone and group ideation will be ideal. Although we cannot provide precise suggestions as to the ideal length of the sessions, it is likely that having the alone session follow the group sessions immediately is best so as to not lose the associational potential of the prior group session which should dissipate or decay over time (Brown & Paulus, 2002).

Even though FTF sessions tend to reduce the number of ideas generated in groups relative to other ways of sharing ideas, this is still a very common and popular approach. The hybrid approach should also be beneficial for enhancing the benefits of FTF brainstorming. This could involve interspersing the verbal exchange sessions with ones in which participants generate ideas privately (either in written form or electronically). Ideas generated in the alone sessions can be shared subsequently with the group and provide cues for additional ideas. This type of paradigm should increase the number of ideas generated relative to using only FTF brainstorming. However, for this type of paradigm to yield more ideas than nominal control condition may require longer sessions (cf., Nijstad et al., 1999) in which those in the control conditions begin running out of ideas before those in the hybrid condition. Hybrid FTF sessions may also have some advantages over solitary sessions in other areas such as the development of group based skills (Sutton & Hargadon, 1999), facilitating subsequent decisions about which ideas to select for implementation, and producing higher levels of task enjoyment (cf., Paulus, et al., 1993).

The modifications in Experiment 2 of reducing social cues in the alone condition and adding another phase did not appear to change the pattern of results among the conditions. Whether the participants in the alone condition work in full view of each other or in isolation does not seem to change the performance of the alone condition relative to the other conditions (in comparison to Experiment 1). It was anticipated that providing extra time might benefit the group and hybrid conditions relative to the alone condition. Nijstad, et al. (1999) found that given enough time, group performance can achieve the level of individual performance. That is, individuals and groups should start running out of ideas over time, but the cues provided in the group setting (both the group and the hybrid conditions) should enable them to continue coming up with new ideas for a longer period of time. We did not find results consistent with that expectation since the pattern of results in Experiment 2 was similar to that of Experiment 1. A substantially longer session might be required demonstrate an enhanced performance of the group condition relative to the alone one and a stronger effect for the hybrid condition relative to the alone condition.

There were no differences in novelty across the three conditions for Experiment 2, but there was an effect of time. Average novelty of the ideas increased as the session progressed across all three conditions. These results are consistent with previous studies suggesting that the more common ideas are generated earlier in the session (Kohn & Smith, 2010; Paulus, Kohn, Arditti, & Korde, 2013). The interaction between condition and time was also significant. The alone condition had the highest novelty at the beginning of the session and lowest novelty at the end of the session. But the patterns were different for the group and hybrid conditions. Thus there is some evidence that

group interaction can enhance the novelty of idea generation, especially in the later phases of brainstorming sessions (see also Baruah & Paulus, 2016).

The results from the mediation models echo the correlation and regressions patterns seen in Tables 3-5. The correlations are stronger for the group condition, and predictions based on the dual pathway model apply better to group condition when using the alone condition as comparison. Although it was expected that participants in the hybrid condition would be able to utilize both pathways to attain novelty, the results indicate that the dual pathway model may not apply as well to the hybrid condition since this condition involves alternating between solitary and group ideation and results in generally lower correlations in performance from one phase to the other. The findings, however, highlight that engaging in hybrid brainstorming entails processes that are different from alone or group brainstorming and do not fit with the dual pathway model but allow for higher levels of performance. The fact that the flexibility and persistence pathways were not related to novelty in the hybrid condition is consistent with that conclusion.

In sum, the experiments have demonstrated the benefits of hybrid brainwriting compared to alone and group brainwriting. This benefit was reflected in number of ideas and the number of categories surveyed. These effects were mostly due to the elevated performance during the alone sessions that followed the group sessions in the hybrid conditions. Apparently, the sharing of ideas in the group phases enhanced both the flexibility and but not the persistence and novelty for individuals in the subsequent alone phases. This series of studies is the first to demonstrate the synergistic benefit of alternating alone and group ideation. Our research suggests in both short-term sessions

and longer-term team interactions, the effective integration of group and solitary ideation is important for effectively tapping group's creative potential. Although hybrid ideation did not increase the novelty of the ideas, past research has found that an increase in the number of ideas is related to an increase in the number of ideas that are both novel and feasible (e.g., Paulus, et al., 2011). Thus this pool of good ideas can then be the basis for developing the best ideas for potential implementation (Kohn et al., 2011).

Figure legends.

Figure 1. Number of unique of ideas generated in the different conditions across phases in Experiment 1.

Figure 2. Number of unique of ideas generated in the different conditions across phases in Experiment 2.

Figure 3. Number of categories explored in the different conditions across phases in Experiment 2.

Figure 4. Number of ideas explored per category in the different conditions across phases in Experiment 2.

Figure 5. Effect of condition on novelty using the dual-pathway model. The model shows the effect of the hybrid and group conditions as compared to the alone condition.

Figure 6. Effect of condition on novelty using the dual-pathway model with direct paths. The model shows the effect of the hybrid and group conditions as compared to the alone condition.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Table 1

Experiment 1: Means and Standard Deviations of Quantity by Conditions and Phases

<u>Phase</u>	<u>Alone</u>	<u>AGAG</u>	<u>GAGA</u>	<u>Group</u>	<u>Overall</u>
Phase 1	41.267 (11.931)	45.133 (9.257)	35.000 (7.874)	34.125 (6.386)	38.742 (9.924)
Phase 2	27.267 (9.924)	26.133 (11.370)	34.938 (8.029)	22.625 (4.365)	27.774 (9.693)
Phase 3	26.667 (10.661)	35.667 (12.715)	24.188 (8.727)	22.938 (4.057)	27.242 (10.527)
Phase 4	24.133 (10.302)	22.333 (8.558)	30.438 (8.981)	19.500 (5.151)	24.129 (9.186)
Overall	119.333 (39.776)	129.267 (35.692)	124.563 (29.003)	99.188 (15.285)	-

Note. Standard deviations (*SD*) are listed in parentheses. There were 15 groups in each condition.

Table 2

Experiment 2: Means and Standard Deviations of Quantity, Novelty, Category Variety and Category Depth by Conditions and Phases

<u>Condition</u>	<u>Quantity</u> (<u>SD</u>)	<u>Novelty</u> (<u>SD</u>)	<u>Variety</u> (<u>SD</u>)	<u>Depth</u> (<u>SD</u>)
Alone				
Phase 1	44.433 (10.190)	2.356 (.265)	14.967 (2.008)	2.965 (.532)
Phase 2	35.500 (10.582)	2.727 (.315)	13.900 (2.369)	2.550 (.633)
Phase 3	34.633 (11.263)	2.777 (.258)	13.067 (2.728)	2.646 (.687)
Phase 4	30.800 (11.223)	2.920 (.292)	12.067 (2.392)	2.551 (.702)
Phase 5	29.533 (12.586)	2.911 (.298)	11.900 (2.695)	2.470 (.894)
Overall	174.900 (49.700)	2.738 (.209)	21.100 (1.845)	8.235 (2.072)
AGAGA				
Phase 1	46.900 (13.422)	2.250 (.216)	14.667 (2.249)	3.179 (.636)
Phase 2	33.567 (9.964)	2.556 (.311)	13.533 (2.161)	2.467 (.580)
Phase 3	39.933 (11.756)	2.893 (.343)	13.967 (2.646)	2.857 (.654)
Phase 4	29.267 (11.298)	3.009 (.441)	11.900 (2.551)	2.440 (.750)
Phase 5	37.367 (14.829)	3.229 (.970)	13.433 (2.208)	2.764 (.920)
Overall	187.033 (55.333)	2.787 (.367)	21.233 (1.832)	8.770 (2.263)
Group				
Phase 1	37.467 (11.004)	2.193 (.240)	12.700 (2.037)	2.928 (.653)
Phase 2	31.433 (11.464)	2.762 (.376)	12.000 (3.118)	2.645 (.826)
Phase 3	28.433 (11.416)	2.929 (.387)	11.333 (2.412)	2.465 (.752)
Phase 4	28.667 (12.408)	3.079 (.358)	11.500 (2.446)	2.459 (.838)
Phase 5	25.300 (12.200)	3.152 (.464)	11.300 (2.842)	2.211 (.978)
Overall	151.300 (56.079)	2.823 (.306)	20.067 (2.132)	7.504 (2.520)
Phase 1s Combined	43.202 (11.968)	2.269 (.248)	14.157 (2.281)	3.036 (.604)
Phase 2s Combined	33.685 (10.613)	2.687 (.117)	13.157 (2.696)	2.567 (.677)
Phase 3s Combined	34.539 (12.208)	2.871 (.335)	12.843 (2.763)	2.663 (.710)
Phase 4s Combined	29.753 (11.504)	3.004 (.372)	11.865 (2.427)	2.491 (.758)
Phase 5s Combined	30.899 (14.028)	3.100 (.655)	12.225 (2.733)	2.493 (.948)
Alone Phases	37.387 (6.128)	2.758 (.319)	13.496 (1.115)	2.748 (.242)
Group Phases	30.591 (3.978)	2.811 (.339)	12.038 (.819)	2.516 (.221)

Note. Standard deviations (*SD*) are listed in parentheses. There were 30 groups in each condition.

Table 3

Experiment 2. Phase 2 group performance correlations with Phase 3 alone performance

	Conditions		
	Alone	Hybrid	Group
Phase 2 Quantity			
Quantity	0.828***	0.731***	0.912***
Novelty	0.568***	0.260	0.510**
Flexibility	0.539**	0.431*	0.634***
Depth	0.656**	0.551**	0.814***
Phase 2 Novelty			
Quantity	0.305	0.050	0.717***
Novelty	0.457*	0.524**	0.679***
Flexibility	0.116	0.332	0.606***
Depth	0.269	-0.162	0.531***
Phase 2 Variety			
Quantity	0.366*	0.429*	0.559**
Novelty	0.057	0.382	0.424*
Flexibility	0.599***	0.269	0.481**
Depth	0.054	0.314	0.453*
Phase 2 Depth			
Quantity	0.764***	0.618***	0.598***
Novelty	0.642***	0.083	0.277
Flexibility	0.277	0.324	0.348
Depth	0.761***	0.494**	0.595***

*** p<.001

** p<.01

*p<.05

Table 4

Experiment 2: Phase 4 group performance correlations with Phase 5 alone performance

	Conditions		
	Alone	Hybrid	Group
Phase 4 Quantity			
Quantity	.921***	.700***	.953***
Novelty	.466**	0.099	.625***
Flexibility	0.348	0.290	.661***
Depth	.858***	.682***	.732***
Phase 4 Novelty			
Quantity	.558**	.518**	.595***
Novelty	.504**	.515**	.612***
Flexibility	0.066	0.285	.405*
Depth	.699***	.456*	0.426
Phase 4 Variety			
Quantity	.447*	.491**	.543**
Novelty	0.229	-0.085	0.292
Flexibility	0.167	0.198	.568***
Depth	.394*	.463**	0.326
Phase 4 Depth			
Quantity	.809***	.545**	.850***
Novelty	.430*	0.071	.573**
Flexibility	0.319	0.221	.517**
Depth	.765***	.549**	.709***

*** p<.001

**p<.01

* p<.05

Table 5.

Experiment 2: Regression results for the relationship of performance in the two alone phases on the final group phase for the hybrid condition.

	Conditions		
	Alone	Hybrid	Group
Ph2 & Ph4 Quantity			
Ph5 Quantity	78.139***	14.649***	143.522***
Ph5 Variety	2.157	1.58	10.613***
Ph5 Novelty	4.509**	0.581	10.366***
Ph5 Depth	41.760***	15.483***	17.520***
Ph2 & Ph4 Variety			
Ph5 Quantity	4.157*	7.243*	8.727*
Ph5 Variety	0.643	0.563	10.790***
Ph5 Novelty	0.754	0.785	1.615
Ph5 Depth	3.093	8.630*	2.001
Ph2 & Ph4 Novelty			
Ph5 Quantity	9.442**	5.729*	14.022***
Ph5 Variety	1.202	1.224	4.031*
Ph5 Novelty	4.883*	8.340*	15.254***
Ph5 Depth	11.912***	4.144*	5.078*
Ph2 & Ph4 Depth			
Ph5 Quantity	35.905***	8.296*	35.672***
Ph5 Variety	1.594	0.805	6.307
Ph5 Novelty	3.058	0.077	7.413*
Ph5 Depth	32.301***	7.956*	14.343***

*** $p < .001$

** $p < .01$

* $p < .05$

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