

HYBRID BRAINWRITING: THE EFFICACY OF ALTERNATING BETWEEN
INDIVIDUAL AND GROUP BRAINSTORMING
AND THE EFFECT OF INDIVIDUAL
DIFFERENCES

by

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Abstract

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Three studies were designed to test the efficacy of hybrid brainwriting procedures as compared to the traditional individual and group brainstorming. The hybrid brainwriting procedures were designed by alternating between individual and group ideation. The first study examined the effect of two hybrid procedures on quantity as compared to the individual brainstorming procedure. Starting the hybrid process with an individual brainstorming phase (AGAG) produced slightly more ideas than doing so with a group phase (GAGA). This hybrid condition (AGAG) was also significantly better than the alone condition. A second study was designed to compare the hybrid conditions to a group condition along with the alone condition, and practice sessions were added to the beginning of each session for all the conditions. This time the results showed that the AGAG condition led to significantly more ideas than the group condition but not the alone condition. The third study tested the hybrid, alone, and group

conditions after making some methodological changes and yielded results consistent with Study 2. The effect of several individual difference variables on idea generation was also tested. The results showed that openness to experience significantly predicted the number of categories explored. Set-shifting ability also had an indirect effect on novelty via the number of categories explored.

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Chapter 1

Introduction

Brainstorming has been used for decades as a tool to generate ideas and solutions to various problems. Since its formal introduction to research and practice by Osborn (1948, 1953, 1957), brainstorming has been widely researched in the fields of psychology, business, and computer science. A typical brainstorming session requires participants to generate as many ideas as they can to a given topic or problem. These ideas are usually expressed using three common methods – talking, writing, or typing. Depending on which of these is used, brainstorming techniques can be classified into face-to-face (FTF) brainstorming, brainwriting (BWr), and electronic brainstorming (EBS). In the early years of brainstorming research, ideas were typically generated verbally in a FTF setting or using BWr techniques. As technology advanced, EBS was developed to overcome some flaws of FTF brainstorming like evaluation apprehension, social loafing, and production blocking (see Diehl & Stroebe, 1987; Karau & Williams, 1993; Lamm & Trommsdorf, 1973). BWr also overcomes these shortcomings of FTF brainstorming (Paulus & Yang, 2000).

Regardless of the technique used to express the ideas (FTF, BWr, or EBS), past research has usually compared the performance of a group to the performance of an equal number of individuals (the nominal group). Previous research has shown that individuals tend to outperform small groups, especially in FTF settings. The goal of this research is to find a way that will help groups perform better by changing the way in which the brainstorming session is structured. This paper focuses on designing a new paradigm – hybrid brainstorming. Hybrid brainstorming is a mix of both individual and group

brainstorming. In his 1957 book, Osborn makes the following statement about using both individual and group ideation:

“...nearly all have agreed that 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.”

--- Osborn, 1957 (pg. 229)

Even though Osborn (1957) discusses the potential of this method, the research has been very limited. This dissertation reviews the literature on hybrid brainstorming paradigms and then moves to a discussion of findings from two preliminary studies using this mixed method. The two studies show a benefit of generating ideas using the hybrid procedure. A third study is designed to enhance our understanding of this paradigm by making important changes to the methodology. In addition to methodological changes, the third study examined the possible role of moderating variables such as personality, perspective taking, and working memory.

Chapter 2

Hybrid Brainwriting

Brainstorming has generally been performed in groups or individually. Although both these methods are useful, they have their own flaws. Two theoretical models can be used to understand the advantages and disadvantages of both these paradigms – the cognitive-social motivational perspective of brainstorming (Paulus and Brown, 2007) and the Search for Ideas in Associative Memory model (SIAM; Nijstad and Stroebe, 2006). According to these models, an idea has the potential to stimulate more ideas. Each concept is associated with multiple other concepts and the activation of one concept can lead to the activation of the other related concepts; those in turn will activate others, and so on. This activation of multiple concepts can lead to more ideas. Jumping quickly from one concept to another can increase the number of categories or concepts being explored, but decrease the depth of the categories explored. Whereas exploring one category thoroughly before moving on to the next one reduces the variety of categories, but it can increase the depth of the categories. Both of these processes – jumping from category to category and digging deeper within a category can lead to more ideas and possibly more novel ideas. Both processes require the person to follow a train of thought. If the train of thought is disrupted, either of these processes may not lead to an increased number of ideas. Individuals who brainstorm alone receive no ideas from others, which means that they are allowed to follow their train of thought. However, they receive no stimulation and can run out of ideas faster than groups. Groups on the other hand have the opposite problem – they receive ideas that can lead to stimulation (Paulus and Brown, 2007) but they can get distracted in the process. It is generally agreed that an idea generated by one

member of the group has the potential to stimulate idea generation for other members in the group (Dennis and Valacich, 1993; Lamm & Trommsdorff, 1973). However, paying attention to other members' ideas could disrupt their thought process causing distraction and information overload (Dennis & Valacich, 1993; Gallupe, Dennis, Cooper, Valacich, Bastianutti & Nunamaker, 1992; Santanen, Briggs, & de Vreede, 2004; Valacich et al., 1994) and could lead to production blocking and production loss (Diehl & Stroebe, 1987; Mullen, Johnson, & Salas, 1991). Production blocking and production loss affect FTF brainstorming more since participants need to wait for their turn to respond. EBS and BWr techniques have overcome some of these issues by allowing participants to generate ideas at their own pace without having to wait for their turn. However, any given idea has the potential to either stimulate idea generation or distract from the train of thought.

Brainstorming groups have the advantage of stimulation along with disadvantage of distraction. Although brainstorming individuals are not distracted, they lack the advantage of stimulation. Once individuals run out of ideas, they do not have the advantage of viewing another person's ideas in order to generate more. So what can be done to overcome these difficulties? One possibility is to combine individual and group brainstorming into a single paradigm to allow participants the benefits of both. If groups are able to have the benefit of stimulation through other members' ideas without being distracted while generating their own ideas, then this should lead to significantly more idea generation than the traditional paradigms. Even so, there has been very limited work on brainstorming procedures that combine the individual and group paradigms. Girotra, Terwiesch, and Ulrich (2010) attempted to create such a paradigm and termed it a 'hybrid process'. In their study, they compared the hybrid condition to a group condition and

asked participants to generate ideas for 30 minutes. 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 study lacked an individual control group, it is not clear whether the use of the hybrid process can allow groups to outperform an equal number of individuals. Extensive literature has shown that real FTF groups are frequently outperformed by nominal groups of the same size (Diehl & Stroebe, 1987; Mullen, Johnson & Salas, 1991; Taylor, Berry & Block, 1958). It is also important to note that the hybrid condition used both brainwriting 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.

Other studies have used a different kind of hybrid process called asynchronous brainstorming. Asynchronous brainstorming is used when participants need to perform as a group, but are not collocated. Participants in this asynchronous group submit their ideas at different points in time. This procedure uses EBS so that all the participants can access the pool of ideas from their own location, at their own time. In this paradigm participants work in a group, which means that they are able to see other members' ideas. That is, ideas are submitted individually, but to a central location or forum that is accessible to all members of the group. Using this paradigm should allow group members to follow their chain of thought without being disrupted, while also being able to gain stimulation from other members' ideas. However, asynchronous brainstorming has not been well researched. Dornburg, Stevens, Hendrickson and Davidson (2009) examined asynchronous brainstorming using a large EBS group that was compared to individual

brainstorming. Participants were asked to come up ideas over the course of four days. There was no difference in the quantity of ideas generated between the individuals and the group. Individuals outperformed the group in originality, feasibility and effectiveness. Among the problems with this study were that the duration of brainstorming was not controlled and it only involved one interactive group of 30. This large EBS group was compared to 39 individuals performing the same task. Therefore, it is difficult to generalize the results found in this study.

De Vreede, Briggs, and Reiter-Palmon (2010) examined another type of asynchronous brainstorming process using multiple groups. These large EBS groups were comprised of smaller groups that either completed the entire brainstorming process, from start to finish (parallel mode) or built on the work provided by the previous subgroups (serial mode). Their results showed that serial processing was better suited for tasks that require in-depth processing and elaboration, while parallel processing was appropriate for tasks that demand multiple new ideas. Again, there was no individual control group.

Ocker and her colleagues (1998) compared FTF brainstorming with two different types of EBS procedures (synchronous and asynchronous) and a combination group. Both of the EBS groups communicated using a computer conferencing system. 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. The amount of time allowed for communication among group members in the asynchronous conditions was not controlled. However, all groups received two weeks to work on the given task. The researchers were interested in the quality and creativity of the solutions

generated. The combined group generated significantly more creative solutions and a better quality solution than the asynchronous, the synchronous and the FTF group. Another interesting finding was that there were no significant differences in the creativity and quality of the solutions generated by the asynchronous and synchronous groups.

Although there is evidence that the hybrid procedure may have some benefit over traditional group brainstorming, the results are not clear. Different studies have used different procedures, different control groups, and even different techniques within the same study. Most of these studies have largely relied on electronic brainstorming and have done so with good reason. EBS was developed to overcome some of the difficulties of FTF brainstorming. All the members in an EBS group can contribute simultaneously to the session (Dennis & Valacich, 1993; Pinsonneault & Barki, 1999; Valacich, Dennis & Connolly, 1994), which reduces production blocking and production loss (Diehl & Stroebe, 1987; Mullen, Johnson, & Salas, 1991). This leads to a drastic increase in the number of ideas generated relative to FTF. Although EBS has many advantages over the traditional FTF method and is an easy to use technique, there are some disadvantages to the EBS method as well. We know that an idea can be stimulating, and depending on the semantic content of the idea it can lead to ideas similar to what were being discussed or can aid in exploration of newer categories of ideas (Paulus, 2000). This stimulation effect can occur only if participants pay attention to these ideas (Dugosh, Paulus, Roland, & Yang, 2000; Paulus & Yang, 2000). In EBS, ideas are visible on a computer screen. As the number of ideas increases, previous ideas get pushed to the top and eventually disappear from view. The only way to access these ideas is to scroll up or down and look for them. Many a times, participants fail to take the extra effort required to read these

ideas. Most participants also tend to look down on the keyboard while typing which causes them to miss new ideas on their screen that are sent by other participants. Therefore, there is no way to be sure that participants are reading all the ideas presented to them. For this reason, this dissertation proposes the use of brainwriting (Heslin, 2009) instead of electronic brainstorming as the procedure of choice. 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).

The following studies test a new hybrid BWr paradigm that overcomes some of the shortcomings of previous studies. The hybrid condition allows participants to generate ideas individually and as a group to help them benefit from both procedures. The condition is broken down into phases that alternate between individual and group brainstorming. Based on the results of the following two studies, a third study was designed to further understand the processes involved in idea generation, and the moderating effect that some variables may have on this new hybrid paradigm.

Study 1

The previously discussed studies lacked an individual control group and most tested only one kind of hybrid procedure. The following study tested two hybrid conditions in comparison to the nominal condition. The two hybrid conditions were created by alternating between group and individual brainstorming. This allowed participants to experience the benefits of both paradigms.

The first experiment employed a mixed design with three brainstorming conditions and four phases in each condition. Participants either switched back and forth from group brainstorming to working alone or generated ideas alone for the entire

session. There were two hybrid conditions depending on which phase was first – alone or group. The three conditions were 1) alone-group-alone-group (AGAG) 2) group-alone-group-alone (GAGA) and 3) alone-alone-alone-alone (Alone). Each phase (alone or group) within the conditions lasted for eight minutes and the total brainstorming session for each condition was 32 minutes long. The sessions in the AGAG and GAGA conditions took place with either groups of three or dyads. Even though participants worked individually in the alone condition, on some occasions there were more than one or two people engaging in the task at the same time.

Based on previously discussed research, the hybrid conditions should lead to more ideas than the nominal condition. In the hybrid conditions participants receive stimulation from other ideas, but they also have time to think on their own and follow their train of thought. Participants in the nominal conditions are not distracted by other people's ideas and are also allowed to follow their train of thought. However, they do not receive any stimulation. Additionally, Paulus and Yang (2000) demonstrated that providing time for participants to reflect on their ideas after the exchange process enhanced idea generation.

H1: Participants in the hybrid conditions will generate more ideas than those in the alone condition.

Although, alternating between the alone and group phase was expected to generate more ideas than the individual condition alone, the order of alternation can also be important. Starting the ideation session individually was expected to be more beneficial than starting the session as group. The first few minutes of ideation are crucial since a large number of ideas are produced at the beginning of the brainstorming session. As time passes by, the number of ideas being generated is reduced. If the first session is

performed individually, participants will have time to write down all the ideas that come to mind without disruption. But if the session is started as a group, then participants may be distracted by ideas of other group members and may lose some of their initial thoughts. This productivity loss can be avoided by allowing participants time to put their thoughts down before entering a group session. Work by Kelly (1988) suggests that there can be an effect of “entrainment” or pacing (Baruah and Paulus, 2007) in a brainstorming task. That is, when ideas are generated at a certain pace, the pace gets carried over from one task to another, in this case from one phase to another. If more ideas are generated in the alone phase as compared to the group phase, then the pace of idea generation should be higher for the alone phase. This rate of ideation should then get carried over to the other phases that follow. Similarly, if rate of ideation is lower as a group, then the lower rate will get carried over to the following phases. This further supports the prediction that AGAG will lead to more ideas than GAGA.

H2: Participants in the AGAG condition will generate significantly more ideas than those in the GAGA condition.

Method

Participants

Undergraduate students from the University of Texas at Arlington participated in the study in order to fulfill their introductory psychology class requirements. Students also had the option of participating in other experiments or writing papers to fulfill the requirement. Participants were randomly assigned to one of the three experimental conditions. A total of 99 students participated in the study. Data from 34 individual participants were collected for the Alone condition, and data from consecutive

participants were then pooled together to create nominal groups of two or three. All the conditions mainly consisted of groups of three, but each condition had two dyads. There were 10 groups of three and 2 dyads in the AGAG and Alone condition, and 11 groups of three and 2 dyads in the GAGA condition. The average age of the participants was 20.44 years ($SD = 3.593$). There were 57 females, 41 males and one participant did not report gender.

Design and Procedure

The study used a 3 (condition) X 4 (Phases) mixed design. Each session was conducted with one to three participants. Participants in the nominal group condition were not necessarily alone in the room, and in some cases two or more participants would perform the task side by side (without sharing their ideas).

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 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 the AGAG and GAGA conditions were given a group practice sessions with the “alternate uses of a paper clip” while those in the Alone condition did not receive a practice session since they were to work individually. For the brainstorming session, participants were asked to generate ideas to the “thumbs problem”. At the end of the session, participants completed a questionnaire about the task and their performance.

Dependent Variables

The number of non-redundant ideas generated was the variable of interest in this study. Average quantity of ideas was used as the dependent variable since the number of members in each group was not the same (two or three). That is, the average number of ideas per person per group was calculated for each phase.

Results

The data were analyzed using a 3 (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, $F(2, 31) = 4.050, p = .027, \eta_p^2 = .207$. The groups in the AGAG condition generated the most number of ideas. Post hoc analyses revealed that the AGAG condition was significantly different from the Alone condition but not from the GAGA condition. Even though participants in the AGAG condition generated more ideas than those in the GAGA condition, the difference may not have been significant due to insufficient power (.678). There was also significant main effect of phases, $F(3, 93) = 45.210, p < .001, \eta_p^2 = .593$, and a significant interaction effect, $F(6, 93) = 33.792, p < .001, \eta_p^2 = .435$. Significantly more ideas were generated in Phase 1 across all conditions

as compared to phases 2, 3 and 4 ($p < .001$). When phase 1 was controlled for, there was no significant difference between the AGAG and Alone conditions. The significant interaction effect highlighted that in the two hybrid conditions, the opposite phases were high, that is, phase 1 and 3 were higher in AGAG, while phase 2 and 4 were higher in GAGA. This is because in the AGAG condition, phase 1 and 3 represent the alone, and in the GAGA condition phase 2 and 4 represent the alone phase. In the Alone condition only phase 1 was high. This pattern of interaction is visible in Figure 1. The interaction effect shows that the pattern of idea generation across phases was different and depended on the condition.

Discussion

Participants in the Alone condition generated the least number of ideas. However, the quantity was significantly different only from AGAG and not from GAGA. AGAG was not significantly from GAGA, but the quantity was much higher in AGAG, which is consistent with the prediction. These findings show that starting the hybrid condition with an alone phase rather than a group phase can lead to an increase in the total number of ideas generated. Most of the ideas were generated in the first phase of the session regardless of the condition. This highlights that the first phase is important and having time to think through and write down one's ideas is essential in the beginning. Starting as a group can disrupt this process and some ideas will be lost. This is evident when the first phases of both the hybrid conditions are compared. Being able to generate more ideas in the first phase increases the pace and this pace seems to get carried over to the following phases (Baruah & Paulus, 2007; Kelly, 1988). The AGAG groups start at a higher rate,

and participants in the GAGA condition never seem to ‘recover’ enough to match the pace in the AGAG condition.

This first study provided insights into the processes involved in the hybrid conditions, and the key finding is that the AGAG condition performs significantly better than the Alone condition. The one finding that is not quite clear from this study is the reason for the difference between quantity of ideas generated in the first phases of the AGAG and Alone conditions. Both these conditions started alone, and their performance in the first phase should not have been different. There are two possible reasons that could have led to this discrepancy – 1) the participants in the Alone condition did not have a practice session, 2) participants in the Alone condition performed the task usually without the presence of other participants. Participants in the AGAG condition, performed the first phase individually, but all three members of the group did so at the same time, in the same room. Therefore, it is possible that they generated more ideas due to presence of social cues that could have led to competition. That is, 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. This meant that they could compare how many ideas they generated as compared to the other members of the group. Previous research has shown that this social comparison can lead to an increase in the number of ideas generated (Dugosh & Paulus, 2005; Paulus & Dzindolet, 1993; Paulus, Larey, Putman, Leggett, & Roland, 1996). Participants in the Alone condition were not exposed to such social cues. Therefore, difference in quantity for phase 1 between the two conditions could be due to social cues, in addition to the lack of practice.

Study 2

Study 1 showed the benefit of hybrid conditions over the Alone condition, especially the AGAG one. However, due to the discrepancy in quantity of the first phases seen in Study 1, some changes to the protocol were required in order to increase confidence in the results. In this study all the conditions started with a group practice session instead of just the hybrid conditions. Participants in the Alone condition also arrived to the lab in groups of three. They performed the task individually, but in the presence of other members of their group. Both these changes were expected to eliminate the gap in productivity for the first alone phases noted in Study 1.

H1: Phase 1 of AGAG = Phase 1 of Alone

Study 1 also found that more ideas were generated in the AGAG condition than in the Alone condition. Like before it is hypothesized that AGAG will lead to more ideas than Alone, since participants in the AGAG condition will have the benefit of receiving stimulation from ideas generated by other group members.

H2a: AGAG > Alone

However, the difference in quantity of ideas generated in the first phases was driving the significance of those results. In the second study it is expected that difference will be eliminated as suggested by hypothesis 1. Therefore it is possible that there will be no significant difference between the AGAG and Alone condition.

H2b: AGAG = Alone

A Group condition was added to test whether the hybrid conditions would lead to more ideas than the group condition. In most real world settings brainstorming is done in groups. It is therefore, important to test if using the hybrid process can be more useful

than the group paradigm. The previously discussed research suggests that groups may experience distraction and may not have enough time to reflect on the ideas they to which they are exposed. Participants in the hybrid conditions should be able to benefit from the stimulation they receive in the group phases since they have time to reflect in it in the alone phases. This is consistent with the Paulus and Yang (2000) findings. Study 1 showed that even within the hybrid condition, starting alone led to more ideas than starting as a group. Therefore, it is expected that the AGAG condition will lead to significantly more ideas than the Group condition.

H3: AGAG > Group

Studies using FTF (Diehl & Stroebe, 1987; Mullen, Johnson & Salas, 1991; Taylor, Berry & Block, 1958) and EBS techniques (Dennis & Williams, 2005; DeRosa, Smith & Hantula, 2007) have consistently shown that nominal groups outperform real groups with four members or less. Since all the groups in this study consist of three members, it is possible that participants will generate more ideas in the alone phases than in the group phase. However, studies that have used BWr techniques have been unable to show a clear benefit for either nominal or real groups. Paulus and Yang (2000) and Coskun (2005) both found that real groups generated more ideas than nominal groups when the brainwriting technique was used. However, the nominal groups generated ideas on a single sheet of paper, while the interacting groups generated ideas on slips of paper. A recent study by Goldenberg, Larson, and Wiley (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 brainwriting technique involved separate slips in all conditions, it was hypothesized that there will be no difference between the alone and group condition.

H4a: The number of ideas generated in the Alone condition will not be significantly different than the number of ideas generated in the Group condition.

However, Study 1 showed participants generated more ideas in the alone phases than they did in the group phases. This may reflect in part the fact that the reading of slips takes time away from individual brainstorming, and this factor is not effectively compensated by increased stimulation. This suggests that even in the brainwriting paradigm, nominal groups may still be able to outperform real groups. Based on these results an alternative hypothesis is predicted.

H4b: Participants in the Alone condition will generate significantly more ideas than those in the Group condition.

Method

Participants

Similar to study 1, participants were undergraduate students from the University of Texas at Arlington 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. Data from the remaining 180 participants were used and all participants were randomly assigned to one of the four experimental conditions. Each condition consisted of 15 groups of three. Like Study 1, data from 45 individual participants were pooled together to create 15 nominal groups. The average age of the participants was 20.16 years ($SD = 3.45$). There were 110 females and 70 males.

Design and Procedure

The study used a 4 (condition) X 4 (Phases) mixed design and all the conditions had groups of three. The basic procedure and instructions were the same as study 1. The only difference was that this time, participants in the Alone condition were in the same room at the same time and they also received a three-minute practice session like the other conditions. The practice topic and brainstorming task topic were same as before. Participants in the Group condition performed the task in the same manner as the other three conditions. The only difference was that they generated ideas as a group in all the four phases.

Dependent Variables

The number of non-redundant ideas generated was the variable of interest in this study. Quantity of ideas was measured for each condition as well as each phase.

Results

The data were analyzed using a 4 (Condition) X 4 (Phases) mixed ANOVA (refer to Table 2 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 and this difference was marginally significant ($p = .056$). The other conditions were not significantly different from one another. There was also significant main effect of phases, $F(3, 174) = 99.365$, $p < .001$, $\eta_p^2 = .631$. Significantly more ideas were generated in Phase 1 ($M = 37.39$, $SE = 1.91$) across all conditions as compared to phases 2, 3 and 4 ($p < .001$). A one-way ANOVA was used to test the differences in the quantity of ideas generated in phase 1 across the conditions. Results showed that there was no significant difference between

the phase 1s of the AGAG and the alone condition, ($p = 1.0$), and phase 1 of the GAGA and group condition also did not differ, ($p = 1.0$). A significant interaction effect was also observed, $F(9, 174) = 13.008, p < .001, \eta_p^2 = .402$. Similar to study 1, the significant interaction effect shows that the pattern of idea generation across phases was different and depended on the condition (see Figure 2).

Discussion

Changes in the procedure eliminated the difference in quantity that was previously seen in the study 1 between the first phases of AGAG and alone. Groups in the AGAG condition generated more ideas than those in the alone condition, but the difference was not significant. The AGAG paradigm led to significantly more ideas than the group paradigm. These results show support for the hypotheses and are encouraging about the potential of hybrid conditions such as AGAG. But we are yet to find strong evidence that AGAG can yield consistently better results than not just the group but also the alone condition. In study 1, the difference in quantity between AGAG and alone was significant, but in study 2 it was not, even though the results were in the expected direction.

The alone condition did not generate significantly more ideas than the group condition. This is consistent with the findings of Goldenberg, Larson, and Wiley (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 (Coskun, 2005; Paulus & Yang, 2000). 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'. This may

lead to distraction and some production loss (Dennis & Valacich, 1993; Gallupe, Dennis, Cooper, Valacich, Bastianutti & Nunamaker., 1992; Santanen, Briggs, & de Vreede, 2004; Valacich et al., 1994). This result does not necessarily indicate the lack of stimulation. The effect of stimulation from group ideation can be seen when comparing within the condition rather than across the condition. For the hybrid conditions, the data (see Figure 1) clearly show an increase in ideas in the alone phase after the group phase, whereas the number of ideas in the nominal condition does not increase at any point during the session. Thus, we see the benefit of stimulation (Dugosh et al., 2000; Paulus, 2000; Paulus & Brown, 2007; Paulus & Yang, 2000), but this benefit is visible not during, but after the group phase. The key is to allow the participants to work individually after a group phase so that they may utilize the stimulation more effectively. These findings highlight the need to focus on hybrid procedures.

The hybrid condition was designed to mimic the way in which ideation often occurs in the real world. Group meetings 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. In the two studies these individual phases occurred in full view of the other group members. Therefore, it is necessary to examine the effect of the hybrid condition when the group members are separated or unable to view each other during the alone phases. A third study was designed to test the effectiveness of the AGAG condition as compared to the Alone condition when the individual brainstorming occurs in isolation.

Another interesting finding from studies 1 and 2 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. Paulus and Dzindolet (1993; Experiment 5) noted that over time, the difference in quantity of ideas between the nominal and interacting groups almost disappears. The number of ideas generated in a 25-minute session by the nominal group drastically declined from about 30 in the first five minutes to six in the last five minutes. On the contrary, Diehl and Stroebe (1991, Experiment 1) were unable to see a sharp decline in the quantity of ideas generated over a 20-minute session. Both of these studies (Diehl & Stroebe, 1991; Paulus & Dzindolet, 1993) expected the decline as nominal groups were expected to run out of ideas towards the end of the session. Knowing that these individuals receive no ideas from other members it was expected that there would be more of a decline in studies 1 and 2 as the session progressed, especially since it was 32 minutes long. It is possible that participants continued to generate ideas due to the social cues present as mentioned before – they were able to see the number of slips used by the other members in the group. 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. Along with the lack of social cues in the alone phases, adding another eight-minute phase to lengthen the session should enhance the chances of seeing a decline in the alone condition.

Based on the results of the first two studies, a third study was conducted to test for differences across conditions after making minor methodological changes. The study also tested for the moderating effect of certain individual difference variables. The next chapter describes the methodological changes followed by the individual difference variables of interest.

Chapter 3

Study 3

The third study compared the hybrid condition to the alone condition, while isolating group members in the alone phases. The session time was increased from 32 minutes to 40 minutes by adding a fifth phase at the end. The procedure remained similar to the first two studies. Along with the two conditions, the study included the group brainwriting condition as an additional control, similar to study 2. Research by Dennis et al. (2005) has suggested that groups may be able to match or possibly exceed the performance of individuals over time. The addition of a group condition provided the opportunity to examine if groups experience the benefit of stimulation and continue to generate ideas at a steady pace even after 40 minutes.

The second study showed that the hybrid condition leads to better performance than the group. To some extent these results can be explained by the stimulation versus distraction hypothesis that was discussed earlier, i.e. the hybrid condition has both benefits – presence of stimulation as well as the lack of distraction. However, it is possible that this increase in performance could simply be due to the way in which available time is divided and used. Group brainstorming divides the time available to the participant between reading and writing. Working individually allows more time to write the ideas. Participants in the hybrid condition go through the group phase two times, while those in the group condition participate in four group phases. This means that their time is divided among reading, writing, and generating ideas, which reduces amount of time available for idea generation. Participants in the hybrid condition have some time to focus only on generating and writing ideas.

Given the multiple processes involved in generating ideas, the process requires certain skills, traits and abilities. For example, building on previously seen ideas (own or others') can help participants generate more ideas. They can also be generated by exploring a category thoroughly, or by jumping from one idea association to another. People who are able to use these processes more effectively should be able to make the most of a brainstorming session. But which traits or skills are required to aid in this process? What factors moderate this process? What person factors, if any, make the hybrid process more effective? Are the same sets of traits useful for all types of brainstorming or do different paradigms require different traits? What can we do to utilize the potential of the hybrid condition to its fullest? For example, can we predict performance in the hybrid condition based on personality traits? How important is perspective taking? The following section discusses some individual difference factors and their particular relevance to the hybrid condition. The methodology of the third study will be described after reviewing the relevant literature for these possible moderators.

Individual Difference Variables

The brainstorming process, like any other task, requires certain capabilities and traits from the individual. The requirements may be different when engaging in individual brainstorming as compared to group brainstorming. Previous research has focused on some individual difference variables, especially in relation to the group paradigm. For example, Larey and Paulus (1999) found the people worked better in groups if they preferred working in groups as compared to those with a low preference. A positive collective orientation has also been shown to predict team performance (Driskell & Salas, 2010). Using the individual brainstorming paradigm, De Dreu, Nijstad, Baas,

Wolsink, and Rokes (2012) found that working memory capacity predicted originality of ideas.

The interesting question is, what happens when both group and individual paradigms are combined together? Traits that are useful in the group paradigm may not be so useful in the individual paradigm and vice versa. Since hybrid conditions have not been extensively studied, we know very little about what they demand from the individuals engaged in them. This section reviews what we know so far about personality and working memory in relation to brainstorming, and makes predictions about their effect on hybrid brainstorming.

Personality

The research on brainstorming and personality traits is limited. Most of the research has focused on personality traits in relation to other divergent thinking tasks. The end goal of brainstorming is to eventually come up with a solution that will help resolve some problem; this process is convergent. However, the process of generating a large number of ideas to reach that solution is a divergent one. This review first discusses some relevant findings from the broad creativity literature and then some additional research from the brainstorming literature.

Most divergent thinking tasks require the ability to think beyond the obvious, and the ability to entertain a ‘strange’ idea without dismissing it prematurely. Openness to experience is one of the most important traits related to creativity, especially divergent thinking. A large body of research suggests that people who are high in openness to experience are more likely to be imaginative and curious (Feist, 2010). Dollinger, Urban,

and James (2004) used the drawing production subtest of the test for creative thinking and found a positive correlation between openness and creativity ratings of the drawings.

Martinsen (2011) created a creative person profile in an attempt to identify the personality traits that predict creativity. His final scale included seven personality factors - instability, ambition, associative orientation, motivation, need for originality, flexibility and agreeableness. He attempted to validate his measure using multiple measures of creativity such as insight, fluency, fluid intelligence, remote associates test, visual arts and writing activities, technical activities, acting, and playing musical instruments. His results revealed that associative orientation showed significant small to moderate positive correlations with fluency, visual arts, and technical activities. Flexibility was positively and significantly correlated with insight, visual arts and writing. Agreeableness and ambition had small positive and significant correlations with acting.

Reviewing the literature on creativity and personality gives a broad idea as to which personality traits might be related to brainstorming. The research on personality and brainstorming has also largely focused on openness and extraversion. Bolin and Neumann (2006) studied the effect of personality on brainstorming groups of four on two brainstorming topics – 1) how to improve your school and 2) the thumbs problem. Their results showed that mean openness to experience was related to increase in quantity and quality of ideas. They also found that extraversion was related to increased quality of ideas. These findings were significant only for the “thumbs problem”, which was also used in the two studies previously described in this paper. Bouchard (1972) also used four person groups, but he used the summated score of the participants on the California Personality Inventory (Gough, 1957) and termed the total score a measure of

interpersonal effectiveness. He divided the participants as high and low on interpersonal effectiveness (I-E). Like Bolin and Neumann (2006), Bouchard (1972) also used multiple brainstorming topics - brand names for a new toothpaste, uses for an old tire, and the thumbs problem. He too found that high I-E predicted better quantity and quality but only for the thumbs problem. Bolin and Neumann (2006) predicted that this increase in quantity related to openness to experience would be caused by lowered evaluation apprehension. However, their results did not provide any evidence of this mediation. Yet, both these studies have found these relationships with personality traits and increased performance on the thumbs problem. It is likely that this relationship with openness is due to the nature of the problem. The thumbs problem asks participants to consider a strange possibility and then generate ideas based on that premise. Individuals who are low on openness to experience might not be able to accept the topic and move on to generating ideas. The idea of something so strange may make them focus on the difficulties and problems that may arise due to the extra thumb, rather than the possibilities it could offer, and thus restrict their flow of ideas. They may be unable to explore different categories of ideas. In addition to being open to a strange brainstorming topic, individuals high on openness were also expected to accept others' ideas more easily than those who are not, and benefit more from the stimulation provided. Therefore, it was expected that being high on openness could be more advantageous in the hybrid and group conditions since they will be exposed to ideas other than their own.

H1: Openness will be positively related to quantity of ideas generated, especially in the hybrid and group conditions.

Those who are low in openness may explore fewer categories since they may find it difficult to explore different categories related to the problem. Since participants in the Alone condition will not be exposed to categories generated by other participants, they may get more fixated on fewer categories.

H2: Openness will be positively related to number of categories explores (category variety), i.e. those who are low on openness may explore fewer categories than those who are high on openness, especially in the Alone condition.

People who are low on openness to experience are also thought to have difficulty in perspective taking (Gurtman, 1995; McCrae & Sutin, 2009). Perspective taking is critical to effective communication. When generating ideas in a group, this communication and exchange of ideas is what leads to the generation of more ideas. Therefore, group brainstorming might not be as beneficial for individuals who are less able to take other people's perspectives. Grant and Berry (2011) found that perspective taking moderated the effect of intrinsic motivation on creativity. They asked participants to generate ideas to help a local band increase their record sales. Participants who thought they had freely chosen the topic and were able to take the perspective of the band members generated more creative solutions. But in this case, the participants had to take the perspectives of imaginary band members that were part of the problem given. If participants are also able to take the perspectives of other group members, does this process enhance ideation? Understanding the other person's perspective and accepting it may also make it easier for participants to build on ideas, which may lead to more quantity of ideas. Once they are able to understand another person's idea they will have

time to better utilize the stimulation they receive from it if they get they are provided with the opportunity to work alone.

H3: Participants who are better at perspective taking will generate more ideas than those who are not, especially in the hybrid and group conditions.

Jung, Lee, and Karsten (2012) divided participants into extroverts or introverts based on the Brown and Philipchalk (1992) 6-item extraversion-introversion measure and assigned them to either high, moderate or low stimulation conditions. Their results showed that extroverts generated the most number of ideas, but only in the moderate and high stimulation conditions. The relationship between extraversion and stimulation was curvilinear. Based on the findings of Jung et al. (2012) –

H4a: Participants who are high on extraversion will generate the most ideas in the hybrid condition, since it has moderate stimulation as compared to the group or alone condition.

Putman (2001), on the other hand, found that extraverts generated more ideas regardless of whether they generated those ideas alone or in a group. If this finding is assumed to be correct then there should be no relationship between level of stimulation and extraversion, that is –

H4b: Participants high on extraversion should generate more ideas than those with low scores, regardless of the brainstorming condition.

Working Memory

The term working memory was used by Atkinson and Shiffrin (1968) to describe short-term memory that can store information and perform different functions on it.

Baddeley and Hitch (1974) proposed a detailed model of working memory with different

components. These included the central executive, the phonological loop, the visuo-spatial sketchpad and the episodic buffer. The central executive is responsible for attention, control, coordination, suppression and retrieval of information. The different kinds of information are stored in the other components. For the purpose of this dissertation the focus will be on the central executive and its functions.

A recent study by De Dreu et al. (2012) examined the relationship between working memory capacity and individual brainstorming. They argue that creativity requires the ability to retrieve ideas from long-term memory and then build on them, as well as the ability to screen relevant vs. irrelevant stimuli - both of which are functions of working memory. Using the dual pathway model (De Dreu, Bass, & Nijstad, 2008), they proposed that participants who have higher working memory capacity will generate more ideas using the persistence pathway (i.e. generating more ideas within a category) as compared to those with lower working memory capacity. They also expected that working memory capacity would not be related to the flexibility pathway (i.e. generating ideas of many different categories). They measured participants' working memory using an online tool for the OSPAN (operational span) task (Unsworth, Heitz, Schrock, & Engle, 2005). The brainstorming task took place a week to three weeks after the working memory assessment and participants were given the topic - "ways to protect, maintain, and improve the environment". They found that working memory predicted originality, and this relationship was partially mediated by persistence, but not flexibility. These results suggest that working memory is an important individual difference variable to consider when studying brainstorming.

De Dreu et al. (2012) assessed these relationships using individual brainstorming and their findings raise interesting questions for further research.

For example, what happens in groups? Does persistence also lead to originality in groups? Or is it harder to stick to one category since participants are exposed to multiple ideas at once? Is flexibility more of an asset in group or hybrid brainstorming? What other subcomponents of working memory could be assessed that would be relevant to group brainstorming?

It is interesting to note that there was no relationship between working memory and flexibility, as predicted by De Dreu et al. (2012). Working memory capacity enables us to go back and forth between tasks, while still being able to hold and process information. This ability should increase flexibility. However, these different aspects of working memory can be measured with different tasks. One measurement tool to assess working memory is usually not sufficient since the construct itself is diverse. Digit span is a commonly used measure of working memory. Participants listen to a string of number and then are asked to recall as many as they can in the correct order. The task starts with two or three digits and then moves on to more depending on how many digits the participant can recall correctly. The maximum number of digits the participant can recall in the correct order is that participant's digit span. De Dreu and colleagues (2012) measured working memory using only one measure, the OSPAN. In the OSPAN task, participants are asked to hold in memory some alphabets while they perform a series of mathematical operations. The task measures how much information a participant can hold and recall while engaging in other tasks. That is, how much new information they can process without losing track of the old information. But working memory does not only

involve screening out irrelevant stimuli, it also involves cognitive flexibility, and cognitive flexibility is an integral part of originality. For example, the Wisconsin card sort test (WCST) was developed as a measure of flexibility of executive function (Berg, 1948). The task requires participants to sort cards and the rules for sorting the card changes without notice to the participant. It measures the ability of the participants to change their response pattern without getting stuck in the previous one. That is, how good are they at changing their line of thought, unlearning old response patterns, and learning new ones. The RSPAN (reading span) task was developed by Daneman and Carpenter (1980) and is strongly related to reading comprehension. Lower scores on RSPAN are associated with inefficient reading processes and therefore, a reduced ability to hold information in working memory. Both of these abilities are important when generating ideas in a group. Since the hybrid condition has both individual and group phases, these factors become important to understand cognitive processes in the hybrid condition as well. Working memory has been shown to have a positive effect on originality via persistence in individuals. However, the research on working memory and group brainstorming is limited. Persistence, that is, focusing on a category and digging deeper may be an artifact of working alone. We know that individuals are able to generate more ideas, because their train of thought is not disrupted. This may make it easier to stay focused on a task or category and lead to persistence. But when working in a group, this very train of thought is disrupted by other ideas that could lead to cognitive stimulation. Those with higher working memory, specifically more focused attention capacity, may be able to still remain persistent while being exposed to other ideas. Those with lower working memory capacity may find it more difficult to do so.

Based on the results from Study 1 and Study 2, the De Dreu et al. (2012) findings, the De Dreu et al. (2008) dual pathway model, and the above discussion on different measures of working memory, the following hypotheses are proposed:

H5: Higher scores on the RSPAN task will be related to higher number of ideas, especially in the hybrid and group conditions since participants will be able to hold their ideas in working memory while they read ideas generated by others.

H6: Higher scores on the OSPAN task will predict more novelty of ideas, mediated by the persistence pathway, especially in the alone condition.

H7: Higher scores on the WCST will predict more novelty of ideas as mediated by the flexibility pathway, especially in the hybrid and group conditions.

H8a: The alone phases will show more category depth (persistence) than the group phases, regardless of condition.

H8b: The group phases will show more category variety (flexibility) than the alone phases.

H9: The hybrid condition will have the highest novelty since participants will be able to utilize both flexibility (in the group phases) and persistence (in the alone phases)

Summary

The previous studies (study 1 and 2) have shown some benefit of generating ideas using the hybrid brainstorming paradigm. However, we are a long way from having “the best” brainstorming paradigm. The previous studies showed that hybrid brainstorming was better than group brainstorming, but not consistently better than individual brainstorming. It was found that some of this inconsistency could be due to the methodology used in the studies. The following section provides a recap of the

methodological changes and moderating variables that will be part of Study 3. Finally, the chapter provides the detailed methodology for Study 3.

Methodological Changes

The methodology of studies 1 and 2 made it difficult to separate the benefit of stimulation from the effect of social cues. In study 3, all the individual phases will take place with partitions placed between participants for all the conditions. This means that the participants will not be able to see each other and will work in isolation. Only the group phases will occur with participants facing each other without the partition. For the hybrid condition, it is important to know if the increase in the number of ideas generated in the alone phase will remain so, even if the alone phase that follows the group phase, occurs in isolation. In addition to teasing apart these two effects – cognitive stimulation and social cues, the methodology for Study 3 more closely mimics how ideas are generated in the real world. The individual ideation phases typically occur in isolation, and not as a group of people working alone on the same problem in full view of each other.

Hypotheses from previous studies were tested again to examine the effect of the methodological changes. Since the participants would be isolated during the individual phases, 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.

H10a: More ideas would be generated in the hybrid condition as compared to the alone condition.

However, participants would be isolated in the individual phases of the hybrid condition as well. If the isolation has the same effect on both conditions the results will be same as before. That is -

H10b: There will no significant difference between the alone and hybrid conditions.

Consistent with the second study, two more hypotheses are proposed.

H11: The hybrid condition should generate significantly more ideas than the group condition.

H12: There will be no significant difference in the number of ideas generated by the alone and group conditions.

If isolating the participants has an effect on quantity, then the number of ideas generated in the alone condition could be reduced. Adding the fifth phase and making the session longer may cause the nominal groups to run out of ideas without any additional stimulation. More ideas could be generated in the beginning of the alone condition as compared to the group condition, but over time this difference might be reduced (Dennis et al., 2005).

H13: There should be an interaction effect between conditions and time on quantity.

Moderating Variables

Although the prior results have shown that the hybrid process is better than simply the group process, we still do not completely understand why this may be the case. Research on individual difference variables like personality, perspective taking, and

working memory suggest that these could be possible factors that could account for some of the variance.

- Big Five Inventory: The 44-item BFI was used to assess extraversion and openness to experience. Participants responded to the 44 statements using a 5-point Likert type scale. Higher scores indicate more openness to experience and higher extraversion. The reported reliability for the scale was .83 (John, Naumann, and Soto, 2008).
- Perspective Taking Scale: The perspective taking 6-item sub-scale from the Empathy Questionnaire (Davis, 1980). The reported reliability was .71 for males and .75 for females. Higher scores on the scale indicate higher perspective taking ability.
- Automated OSPAN & RSPAN: The automated versions of the operational span and reading span were obtained from the Dr. Engle's Attention and Working Memory lab. Total scores from both measures were used for analyses. Higher total scores on both these measures indicate higher working memory. The internal consistency for automated OSPAN was reported to be .86 and for automated RSPAN was .88 (Redick et al., 2012)
- WCST-64: The computer version 2 of the WCST was used for this study. Raw scores for perseverative errors were used for analyses (Owen et al., 1993), More number of perseverative errors indicate lower ability to shift set. The correlation between the perseverative error scores on the WCST-64 and the WCST-128 was .90 (Purdon and Waldie, 2001).

Method

Participants

Participants were recruited from the University of Texas at Arlington using the SONA system. All participants received research credits to help them 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 less 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 295 students participated in the first part of the study. Twenty-five students did not return to the lab to complete the second part. Data from 270 students were used for the analyses. 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 remainder 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 study used a 3 (condition) X 5 (Phases) mixed design and all of the conditions had groups of three participants. The study was divided into three parts. The first part of the study was to be completed online and participants were asked to respond to the perspective taking scale as part of their prescreen on the SONA system. The BFI

was completed in the lab on their first day. These measures were completed prior to the brainstorming session. In addition to the personality measures, participants were asked to complete different tasks individually that measure working memory and executive function for the second part of the study. The reading span test (RSPAN), the operational span test (OSPAN), and the Wisconsin card sort test (WCST) were completed on the computer. The computer program calculated their scores on the OSPAN, RSPAN, and WCST. For the analyses, mean scores on all the moderating variables were calculated at the group level.

Once participants completed the first part of the study, they were able to participate in the brainstorming part. Participants reported to the lab in groups of three to complete the brainstorming task. Similar to study 1 and 2, 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 the topic was “alternate uses of a paper clip”. 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 partition in place, stopping every eight minutes for a change of pens. Each phase lasted for eight minutes just as the previous studies. 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 study questionnaire, they were debriefed and thanked.

Dependent Variables

A number of dependent variables were measured for analyses. These included – quantity, novelty, category depth, and category variety. The number of non-redundant ideas generated was the basic outcome variable of interest in this study. 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 are 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 on the basis of 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 means “very common” and five stands for “very uncommon”.
- **Category variety (Flexibility):** Ideas were also sorted into different categories. Using previous data, 24 categories were developed for the thumbs problem. Some of those categories were social/discrimination, sports, gestures, etc. (see Appendix E for full list and description). 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.

Results

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 novelty and quantity were computed for each phase, and overall (for each session).

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 were counted. Additionally, the number of non-redundant categories

explored throughout the entire session were 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 category variety by the number of non-redundant ideas for the corresponding phase and/or session.

Comparing Means

Before testing the more complex hypotheses, four separate 3 (Condition) x 5 (Phases) mixed ANOVAs were used to test the differences between conditions and phases on each of the four dependent variables – quantity, novelty, category variety, and category depth (refer to Table 3 for descriptive statistics).

The ANOVA for quantity yielded a significant main effect of condition, $F(2, 87) = 3.430, p = .037, \eta_p^2 = .073$. 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 than the group condition, $p = .035$. The other differences between conditions were not significant. There was also a main effect of phases, $F(4, 348) = 86.179, p < .001, \eta_p^2 = .498$. As expected, the most number of ideas were generated in the first phase and quantity declined as the phases progressed. Phase 1 was significantly different than all the other phases at $p < .001$. Phase 2 and phase 5 were significantly different at $p = .037$. Phase 2 and phase 3 were not significantly different from each other, and phase 4 and 5 were not significantly different from each other (see Table 3 for descriptive statistics). The interaction between condition and phase was also significant, $F(8, 348) = 8.829, p < .001, \eta_p^2 = .169$. The results show that the pattern of idea generation varied across condition depending on the brainstorming phase (see Figure

3). Similar to study 1 and study 2, the hybrid condition led to the most ideas as compared the group and alone condition. Consistent with study 2, only the difference between the hybrid and group condition was significant. Isolating the participants in the individual brainstorming phases and adding another 8-minute phase did not lead to a significant difference between the hybrid and alone conditions. The increase in quantity in the third and fifth phase of the hybrid condition indicates a benefit of stimulation they received from the previous group brainstorming phases. Since there were no social cues available in this study, the results suggest that this increase in quantity may be purely due to stimulation. The third phase (alone) in the hybrid condition was significantly different from the second phase (group) within the condition ($p < .001$). The fifth phase (alone) was also significantly different than the fourth phase (group) ($p < .001$). Comparing the fifth phase across the three conditions showed that significantly more ideas were generated in the hybrid condition as compared to the group condition ($p = .002$) and marginally significantly more than the alone condition ($p = .074$).

The second ANOVA tested for differences in novelty of the ideas across conditions and phases. There was no significant main effect of condition, $F(2, 87) = .604$, $p = .549$, $\eta_p^2 = .014$. 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. All the phases were significantly different from each other ($p < .001$), except phases 4 and 5 ($p = 1$). 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 Figure 4). In the first phase, participants in the alone condition generated ideas with significantly higher average novelty than participants in the group condition ($p = .032$).

By the fifth phase, the hybrid and group conditions showed higher novelty than the alone condition. However, the comparison was not significant (hybrid – $p = .176$; group – $p = .450$).

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 ($p = .010$) and hybrid condition ($p = .001$). The alone and hybrid condition did not differ significantly from each other. 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. That is, more categories were explored early in the session than later. Phase 1 was significantly different than phase 2 ($p = .003$) and all the other phases ($p < .001$). Phase 2 was significantly different from phase 4 ($p < .001$) and 5 ($p = .037$). Phase 3 was significantly different from phase 4 ($p = .004$), and phases 4 and 5 were not significantly different. The interaction effect was significant, $F(8, 348) = 2.846, p = .004, \eta_p^2 = .061$. Even though category variety declined over time, the pattern was different in the hybrid condition as compared to the alone and group conditions (see Figure 5). 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 analysis for category depth revealed no main effect of condition, $F(2, 87) = .790, p = .457, \eta_p^2 = .018$. 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 was significantly higher in the first phase as

compared to all the other phases ($p < .001$), and marginally significant in phase 3 as compared to phase 4 ($p = .064$). The other phases were not significantly different from each other. The interaction between phase and condition on category depth was significant, $F(8, 348) = 2.846, p = .004, \eta_p^2 = .061$. Similar to the pattern of interaction seen for category variety, category depth increased in phase 3 and phase 5 of the hybrid condition, after the group brainstorming phase (see Figure 6). Category depth was significantly higher in phase 3 as compared to phase 2 ($p = .007$), but phase 4 and phase 5 were not significantly different ($p = .132$).

It was expected that category depth would be higher in the alone phases as compared to the group phases, regardless of condition. 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 showed that the alone phases had significantly higher category depth than the group phases, $t(29) = 5.776, p < .001$. Therefore, hypothesis 8a was partially supported. Category depth was higher in the alone phase, but only in the hybrid condition. There was no significant difference between the alone and group conditions.

Category variety was expected to be higher in the group phases as compared to the alone phases, regardless of condition. Both the dependent and independent t -tests were used to test the hypothesis. The independent t -test showed a significant difference in category variety between the alone and group conditions, $t(58) = 2.007, p = .049$.

Contrary to the hypothesis, the alone phases had higher variety than the group phases. The dependent t -test also yielded a significant difference, $t(29) = 4.050, p < .001$. Hypothesis 8b was not supported since category variety was higher in the alone phases. Mediation model for condition. It was expected that the hybrid condition would have the highest novelty since participants would be able to use both flexibility and persistence. 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, in press). 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 7) 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 8). 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.

Moderated Regression Analyses

Several moderated regression models were used to test the effects of the personality variables on the idea generation process. Since condition was a categorical variable with three levels, two unweighted effects codes were created to represent the variable. All the continuous variables (openness, perspective taking, extraversion, and scores on the RSPAN) for each model were centered on the mean. Cross products were created using the unweighted effects codes and the centered variables to represent the corresponding interaction terms.

The first hypothesis suggested that openness would be positively related to quantity of ideas and that this relationship would be stronger in the hybrid and group conditions. There was a significant main effect of condition, $\Delta R^2 = .083$, $\Delta F(2,84) =$

3.820, $p = .026$. The group condition produced significantly fewer ideas than the mean, $b = -20.878$, $SE = 8.335$, $t(84) = -2.505$, $p = .014$, $sr^2 = .068$. The hybrid condition led to more ideas as compared to the mean, $b = 18.692$, $SE = 8.359$, $t(84) = -2.236$, $p = .028$, $sr^2 = .054$. Contrary to the hypothesis, there was no main effect of openness on quantity, $\Delta R^2 = .005$, $\Delta F(1,84) = .477$, $p = .492$. Although the relationship between openness was not significant, it was in the expected direction, $b = 10.473$, $SE = 15.169$, $t(84) = .690$, $p = .492$, $sr^2 = .005$. The interaction effect between openness and condition was not significant, $\Delta R^2 = .014$, $\Delta F(2,84) = .635$, $p = .533$ and the first hypothesis was not supported.

It was also expected that openness would be positively related to category variety and that lower openness would lead to lower category variety especially in the alone condition. There was a significant main effect of openness on category variety, $\Delta R^2 = .082$, $\Delta F(1,84) = 8.297$, $p = .005$. Higher scores on openness were positively related to more category variety, $b = 1.502$, $SE = .521$, $t(84) = 2.881$, $p = .005$, $sr^2 = .082$. There was no significant main effect of condition, $\Delta R^2 = .046$, $\Delta F(2,84) = 2.348$, $p = .102$, and there was no significant interaction effect, $\Delta R^2 = .009$, $\Delta F(2,84) = .478$, $p = .622$. The second hypothesis was partially supported since openness was positively related to category variety, however the relationship was not moderated by condition.

Perspective taking was expected to predict quantity of ideas, especially in the hybrid and group conditions. There was no main effect of perspective taking, $\Delta R^2 = .028$, $\Delta F(1,84) = 2.626$, $p = .109$. The results were in the expected direction, but they were not significant, $b = 28.659$, $SE = 17.686$, $t(84) = 1.620$, $p = .109$, $sr^2 = .028$. As previously noted, condition predicted quantity of ideas, $\Delta R^2 = .066$, $\Delta F(2,84) = 3.110$, $p = .050$, and

there was no interaction effect, $\Delta R^2 = .009$, $\Delta F(2,84) = .448$, $p = .641$. The third hypothesis was not supported.

The fourth hypothesis was divided into parts – a) extraversion was expected to predict quantity in the hybrid condition alone, b) extraversion would predict quantity regardless of the condition. The results show no main effect of extraversion, $\Delta R^2 = .001$, $\Delta F(1,84) = .061$, $p = .805$. Condition was found to predict quantity, $\Delta R^2 = .070$, $\Delta F(2,84) = 3.240$, $p = .044$, but there was no interaction effect, $\Delta R^2 = .014$, $\Delta F(2,84) = .642$, $p = .529$. The fourth hypothesis was not supported since extraversion did not predict quantity and there was no interaction effect.

It was expected that higher scores RSPAN would predict higher quantity of ideas, especially in the hybrid and group conditions. The results showed a main effect of condition on quantity, $\Delta R^2 = .073$, $\Delta F(2,84) = 3.363$, $p = .039$. But there was no significant main effect of RSPAN, $\Delta R^2 = .011$, $\Delta F(1,84) = .986$, $p = .324$, and no significant interaction effect, $\Delta R^2 = .014$, $\Delta F(2,84) = .644$, $p = .528$. The fifth hypothesis was not supported.

Mediation Models

Two mediation models were proposed based on the results of the first two studies presented in this paper and the findings of De Dreu et al. (2008; 2012). Both models predicted novelty of the ideas generated using two mediators – flexibility (category variety) and persistence (category depth). One model used scores on the OSPAN and the other used scores on the WCST. OSPAN was expected to predict novelty through the persistence pathway and WCST was expected to predict novelty through the flexibility pathway. Since the direct path from the predictor to the dependent variable in each model

was not of interest to the hypotheses, it was not included in any of the base models (i.e. it was fixed to zero). Therefore, the total effect in the models was equal to the indirect effect ($c = c' + ab$; where $c' = 0$).

These models were examined using AMOS. The predictors and mediators were centered on the mean before entering them into the parallel mediation models. Since there were two mediators, specific indirect effects were examined in AMOS by using the “create a new estimand” command and adding a few lines of code¹. This produced bootstrap estimates of the specific indirect effects along with the standard errors, bias corrected confidence intervals, and p values. Bootstrapping with 5000 samples was used to estimate direct, indirect, and total effects with bias corrected confidence intervals at 95%.

OSPAN. The first mediation hypothesis suggested that effect of OSPAN predicted novelty via persistence and that this effect would be strongest in the alone condition. To test the overall effect, all the groups from the three conditions were used in the first model (Figure 9). The global-type omnibus test-fit of entire model indicates that the model is not a good fit. The chi-square was marginally significant, $X^2(2) = 5.694, p = .058$, indicating that the model is significantly different from the data and does not fit well. The GFI (.970) was above the recommended cut off, but the AGFI (.849), and CFI (.882) were below the accepted cut off (.95) indicating that the model was not a good fit. The RMSEA (.144) was not significant ($p = .096$); since the value was not close to zero or less than .05 the index indicates that the model was a poor fit.

¹ The code used to create the specific indirect effects was obtained from the AMOS website

The modification indices suggest that adding the correlational path between the errors terms of persistence and flexibility would significantly improve the model fit. Two other suggestions made by the modification indices were a path from category depth to category variety or from category variety to category depth. However, the paths between category variety and depth did not make theoretical sense. It was not expected that one would lead to the other. But a correlation between their error terms is understandable due to the way the two variables are calculated – category depth is category variety divided by number of ideas. Therefore, the correlation between the two error terms was added and the model was tested again with the new path (Figure 10). This time the chi-square was not significant, $\chi^2(1) = .039, p = .843$. The model was not significantly different from the data. GFI (.999) and AGFI (.993) were above the recommended cut off (.95), and CFI (1.0) was over .90. The fit indices along with the chi square suggested that the model fit the data well. The RMSEA was 0 ($p = .848$), which was well within the recommended range ($< .05$). The chi-square difference test was significant, $\chi^2(1) = .5655, p = .017$, suggesting that the model with the correlated errors fit the data significantly better than the base model. The AIC for the new model was 18.093, which was smaller than the AIC for the base model (21.694), again indicating that the model with the correlated errors was a better fit.

Surprisingly, the model showed that scores on OSPAN did not significantly predict category depth ($b = .020, CI: -.144, .146, SE = .082, t = .247, p = .805$) or category variety ($b = -.035, CI: -.144, .146, SE = .069, t = -.511, p = .805$). Although the paths were not significant, the direction of the relationships is consistent with the

prediction. OSPAN was positively related to category depth, but negatively related to category variety. Both category variety ($b = .061$, $CI: .024, .103, .146$, $SE = .015$, $t = 4.733$, $p < .001$) and depth ($b = .070$, $CI: .048, .094$, $SE = .082$, $t = .247$, $p = .805$) significantly predicted novelty. The indirect effect of OSPAN on novelty via category depth was not significant ($b = -.001$, $CI: -.010, .010$, $SE = .005$, $p = .783$). The indirect effect on OSPAN on novelty via category variety was also not significant ($b = -.002$, $CI: -.011, .005$, $SE = .004$, $p = .483$). As can be seen, the total indirect effect was also not significant, ($b = -.001$, $CI: -.019, .013$, $SE = .008$, $p = .905$). The total effect of OSPAN on novelty was not significant as it was equal to overall indirect effect (the direct effect was fixed to zero). Since OSPAN was positively related to one mediator and negatively related to the second mediator, and the strength of the relationships was similar, the total effect was close to zero and it suggested opposing mediation. However, none of the specific indirect paths were significant, indicating a lack of mediation. The overall model did not support the first part of the hypothesis since there was no mediation, but the model was still tested using multi-group analysis in AMOS to check for differences across conditions.

The previously tested model was renamed as the unrestricted model and a second model was specified where the regression estimates were fixed to be equal to one another across groups. Doing so allowed the researcher to examine if the regression weights were different across conditions. The chi-square for the unrestricted model was not significant, $X^2(3) = 1.382$, $p = .710$, but the chi-square for the equal loadings model was marginally significant, $X^2(11) = 19.352$, $p = .055$. The chi-square difference test was significant, $X^2(8) = 17.97$, $p = .021$. The equal loadings model fit the data significantly worse than the

unrestricted loadings model. The GFI and AGFI for the unrestricted model (.992 and .922) were over the cut off point or closer to the cut off as compared to the GFI and AGFI for the equal loadings model (.903, .736). The AGFI was below the recommended cut off, but that is understandable in this case since the model was tested on a total of 90 groups, which were divided into 3 groups of 30 for the multi-group analysis. The AGFI corrects for sample size, and since the sample size for the model was very small the AGFI was below the recommended cut off point. Even so, the AGFI was much closer to the cut off for the unrestricted loadings model as compared to the equal loadings model. The CFI for the unrestricted model was 1.0, whereas for the equal loadings model it was .837. The RMSEA for the unrestricted model was .000 (*CI*: .000, .133, $p = .773$) and for the equal loadings model was .093 (*CI*: .000, .161, $p = .143$). Although both values were not significantly different from zero, the unrestricted model had the lower value. The AIC for the unrestricted model (55.382) was also lower than the AIC for the equal loadings model (57.352). Overall, the global fit indices suggest that unrestricted loadings model fits better than the equal loadings model. Therefore, the regression weights of the estimated paths were not equal across conditions. Next, regression weights for each of the estimated paths were examined for the three conditions separately.

Alone Condition. Similar to the overall model, OSPAN did not predict category depth ($b = .011$, *CI*: -.107, .149, $SE = .066$, $p = .794$) or category variety ($b = .078$, *CI*: -.041, .169, $SE = .053$, $p = .189$) for the nominal groups. Interestingly, the direction of the relationship between OSPAN and category variety changed from negative in the overall model, to positive for the alone condition. In the overall model, both category depth and variety predicted novelty. However, for the alone condition only category depth predicted

novelty ($b = .067$, $CI: .031, .100$, $SE = .017$, $p = .001$), while the effect of category variety on novelty was not significant ($b = .013$, $CI: -.015, .040$, $SE = .014$, $p = .312$). Again, the indirect effect of OSPAN on novelty via category depth was not significant ($b = .001$, $CI: -.008, .009$, $SE = .004$, $p = .788$) and neither was the indirect effect of OSPAN on novelty via category variety ($b = .001$, $CI: -.001, .005$, $SE = .001$, $p = .228$). The overall indirect effect (also equal to the total effect) was not significant ($b = .002$, $CI: -.008, .009$, $SE = .005$, $p = .659$). There was no mediation in the alone condition, and the results do not support the hypothesis (See Figure 11).

Hybrid Condition. OSPAN did not significantly predict category depth in the hybrid condition ($b = -.035$, $CI: -.148, .087$, $SE = .061$, $p = .597$), but it did predict category variety ($b = -.138$, $CI: -.234, -.054$, $SE = .045$, $p = .001$). For the hybrid conditions both these relationships were negative, indicating lower scores on OSPAN predicted higher category depth and significantly higher category variety. Category depth did not predict novelty ($b = .014$, $CI: -.036, .052$, $SE = .022$, $p = .552$), but category variety significantly predicted novelty ($b = .096$, $CI: .061, .139$, $SE = .020$, $p = .001$). The indirect effect of OSPAN on novelty via category depth was not significant ($b = -.001$, $CI: -.007, .002$, $SE = .002$, $p = .423$). However, the indirect effect of OSPAN via category variety was significant ($b = -.013$, $CI: -.024, -.004$, $SE = .005$, $p = .003$). The overall indirect effect was marginally significant, $b = -.014$, $CI: -.025, -.004$, $SE = .017$, $p = .060$. The results showed mediation - lower scores on the OSPAN predicted higher category variety, and higher category predicted higher novelty (See Figure 12).

Group Condition. The direction of the regression weights for the group condition closely resembled the direction of the estimates in the overall model as compared to the

other two conditions. OSPAN did not significantly predict either mediator (category depth: $b = .020$, $CI: -.152, .143$, $SE = .073$, $p = .826$; category variety: $b = -.035$, $CI: -.171, -.074$, $SE = .062$, $p = .571$). Also, both category depth ($b = .070$, $CI: .046, .093$, $SE = .012$, $p = .004$) and category variety ($b = .061$, $CI: .021, .101$, $SE = .021$, $p = .003$) significantly predicted novelty. None of the specific indirect effects were significant (via depth: $b = .001$, $CI: -.011, .011$, $SE = .005$, $p = .808$; via variety: $b = -.002$, $CI: -.011, .005$, $SE = .004$, $p = .835$). The overall indirect effect also was not significant, $b = -.001$, $CI: -.021, .012$, $SE = .008$, $p = .460$. There was no mediation effect in the group condition (See Figure 13).

Overall, the 6th hypothesis that OSPAN predicted novelty via persistence (category depth), especially in the alone condition was not supported. However, evidence of mediation was found in the hybrid condition, but the mediator was flexibility (category variety) and not persistence.

WCST. To test the second mediation hypothesis, the same procedure was followed – first, an overall model was tested, and then a multi-group analysis was performed. It was expected higher performance on the WCST would predict higher novelty through the flexibility pathway, especially in the hybrid and group conditions. The overall model (tested with all 90 groups, see Figure 14) had significant chi-square, $X^2(2) = 8.218$, $p = .016$ indicating that the model did not fit the data well. Other omnibus fit indices also suggested that the model was not a good fit to the data. The GFI was above the cut off at .958 and AGFI was below the cut off at .788 (cut off: .95). The CFI (.832) was below the cut off (.90). The RMSEA was .187 ($CI: .068, .327$) and was significantly different than zero ($p = .033$). Similar to the mediation model with OSPAN as the

predictor, the modification indices suggested that the error terms for category depth and variety be correlated to improve the fit of the model or a path be added from depth to variety (or vice versa). As previously explained, the correlated error terms made theoretical sense and therefore, the correlation path was added and the model was tested again (Figure 15). This time the chi-square was not significant ($X^2(1) = .385, p = .535$) and the model fit the data. Other modification indices were in agreement with the chi-square. The GFI (.998) and AGFI (.978) were above the recommended cut off, as was the CFI (1.0). The RMSEA was .000 (*CI*: .000, .238) was not significant ($p = .578$). The AIC for this model was 18.385, which was lower than the AIC for the model without the covariance path (24.218), indicating a better fit. The chi-square difference test was significant, $X^2(1) = 7.833, p = .005$ suggesting that the model with the correlated errors fit the data significantly better and the model with the correlated error terms was used for further analyses.

Higher perseverative errors on the WCST did not significantly predict category depth ($b = .187, CI: -.055, .445, SE = .127, p = .117$) but predicted category variety, and the effect was marginally significant ($b = -.229, CI: -.045, .020, SE = .125, p = .073$). Both category depth ($b = .045, CI: .023, .062, SE = .010, p = .001$) and category variety ($b = .048, CI: .028, .072, SE = .011, p = .001$) significantly predicted novelty. The indirect effect of WCST on novelty via category depth was not significant ($b = .008, CI: -.001, .023, SE = .006, p = .085$), but the indirect effect via category variety was marginally significant ($b = -.011, CI: -.025, .000, SE = .006, p = .056$). This finding is consistent with the hypothesis. The overall indirect effect was not significant, $b = -.003, CI: -.022, .018, SE = .010, p = .788$. Since the two specific indirect effects were of similar

magnitude but opposite directionality, the overall indirect effect is close to zero; again suggesting opposing mediation.

As predicted, higher scores on WCST did lead to higher novelty via the flexibility pathway. Multi-group analysis was then performed using the model to test for differences across conditions. The same procedure that was used to test the OSPAN models was followed to test these models. The unrestricted loading models and equal loadings model. The chi-squares for both the models were not significant, although the unrestricted model had a lower chi-square value ($X^2(3) = .477, p = .924$) as compared to the equal loadings model ($X^2(11) = 14.845, p = .190$). The chi-square difference test was marginally significant, $X^2(8) = 14.369, p = .073$. The GFI (.997) and AGFI (.973) were higher for unrestricted model than the equal loadings model (GFI: .925, AGFI: .796). The CFI was also higher for the unrestricted model (1.0) as compared to the equal loadings model (.930), but both were above the cut off. For the unrestricted loadings model the RMSEA was .000 ($CI: .000, .059; p = .943$), and .063 ($CI: .000, .138; p = .350$) for the equal loadings model. The AIC was higher for the unrestricted model (54.477) as compared to the equal loadings model (52.845). The omnibus fit indices and comparative fit indices indicate that both models could fit the data fairly well. Based on the higher GFI, AGFI, and CFI values along with the lower chi-square and lower RMSEA, it was decided that the unrestricted loadings model fit the data better than the equal loadings model; especially since the chi-square difference test was marginally significant. Multi-group analysis was conducted to examine the difference in regression weights across conditions.

Alone Condition. Number of perseverative errors on WCST did not significantly predict category depth ($b = .399, CI: -.218, .924 SE = .306, p = .237$), but significantly

predicted category variety ($b = -.419$, $CI: -.823, -.053$, $SE = .191$, $p = .027$) in the nominal groups. Fewer perseverative errors predicted higher category variety. For the alone condition, higher category depth predicted higher novelty ($b = .067$, $CI: .031, .101$, $SE = .017$, $p = .002$), but category variety did not predict novelty ($b = .013$, $CI: -.016, .040$, $SE = .014$, $p = .329$). Both the specific indirect effects were not significant (via depth: $b = .027$, $CI: -.011, .068$, $SE = .021$, $p = .221$; via variety: $b = -.005$, $CI: -.028, .004$, $SE = .008$, $p = .262$) and the overall indirect effect was also not significant, $b = .021$, $CI: -.029, .066$, $SE = .025$, $p = .396$. There was no mediation in the alone condition (See Figure 16).

Hybrid Condition. WCST did not significantly predict category depth ($b = .303$, $CI: -.067, .568$, $SE = .160$, $p = .102$) or category variety ($b = -.040$, $CI: -.369, .361$, $SE = .186$, $p = .798$). Category depth did not predict novelty ($b = .014$, $CI: -.036, .052$, $SE = .022$, $p = .552$), but category variety did ($b = .096$, $CI: .061, .139$, $SE = .020$, $p = .001$). Higher category variety predicted higher novelty. The specific indirect effects were not significant (via depth: $b = .004$, $CI: -.008, .023$, $SE = .007$, $p = .383$; via variety: $b = -.004$, $CI: -.037, .036$, $SE = .018$, $p = .780$). The regression weights for the specific indirect paths were had the same absolute value, but opposite directionality. Like some of the models seen previously, this seems to suggest opposing mediation. Based on the two specific indirect effects, the overall indirect effect was equal to zero ($b = .000$, $CI: -.033, .045$, $SE = .020$, $p = .979$). There was no mediation in the hybrid condition and the results did not support the hypothesis (See Figure 17).

Group Condition. WCST did not significantly predict category depth ($b = -.071$, $CI: -.495, .300$, $SE = .197$, $p = .672$) or category variety ($b = -.284$, $CI: -.638, .317$, $SE = .247$, $p = .302$). Fewer perseverative errors were associated with increased depth and

variety, but the effect was not significant. Both mediators significantly predicted novelty in the group condition (depth: $b = .070$, $CI: .048, .094$, $SE = .011$, $p = .001$; variety: $b = .061$, $CI: .024, .103$, $SE = .020$, $p = .002$). The specific indirect effects were not significant (via depth: $b = -.005$, $CI: -.034, .022$, $SE = .014$, $p = .657$; via category: $b = -.017$, $CI: -.051, .017$, $SE = .017$, $p = .212$) and neither was the overall indirect effect ($b = -.022$, $CI: -.062, .029$, $SE = .023$, $p = .288$). There was no mediation in the group condition and the results did not support the hypothesis. Overall, the 7th hypothesis was partially supported since WCST predicted novelty via the flexibility pathway, but the mediation was not significant for the hybrid or group conditions (See Figure 18).

Discussion

The results of the third study were consistent with the results of studies 1 and 2 as seen from the ANOVA on quantity. The individual difference variables did not yield the expected results. The findings for condition and for the individual difference factors are discussed below in two separate sections.

Effects of conditions

The third study was designed to better understand the pattern of idea generation seen in the first two studies. Consistent with the second study, the hybrid condition generated the most ideas, but the difference was only significant when compared to the group condition. There was a main effect of time – quantity decreased as the session progressed. There was also a significant interaction effect between condition and phase. There was no significant difference in quantity between the hybrid and the alone condition. It was thought that participants in the alone condition of the second study might have been motivated to continue generating ideas throughout the 32-minute session

due social cues they received by watching other participants performing at the same time in the experimental room. This reasoning was consistent with the social influence model (Paulus and Dzindolet, 1993; 2008), which suggests that the presence of such social cues could be motivational. To minimize social cues, a partition was placed between participants during the individual brainstorming phases of the alone and hybrid conditions in the third study. It was expected that the lack of social cues would reduce the number of ideas generated in the alone condition, and lead to a significant difference between the alone and hybrid conditions. However, this was not the case. It seems that adding the partition to reduce social cues did not have much of an effect on quantity in Study 3.

The fifth 8-minute phase was added to all the conditions in the third study to examine if the decline in quantity would be more evident over a longer period of time for the alone condition in comparison to the other conditions. Comparing the just the fifth phases across conditions showed that the hybrid condition yielded significantly more ideas than the group condition and marginally more than the alone condition. The hybrid condition was able to generate more ideas after being exposed to the ideas of other group members in the group phases. Without similar stimulation for those in the alone condition, quantity continued to decline, albeit at a slow pace. Overall, it seems that the hybrid condition was able to benefit from the group phases. However, participants in the alone condition seemed to generate slightly more ideas than the group condition without external stimulation. One possible reason is that the thumbs problem allows for a large variety of ideas. It is also possible that these participants in the alone condition were able to build on their own ideas, using them as stimulation, but this could not be assessed in

the present study. Even so, it seems that the hybrid condition provides some benefit over the alone condition.

There were no differences in novelty across the three conditions, but there was an effect of time. Average novelty of the ideas increased as the session progressed. Novelty of ideas increased from phase 1 to 5, and this trend was consistent across all three conditions, regardless of the type of brainstorming (individual or group). 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; Ward, Sifonis, & Wilkenfeld, 1996). The interaction between condition and time was also significant. Although there was no overall difference among conditions, the alone condition had the highest novelty at the beginning of the session, and lowest novelty at the end of the session. The group condition had the lowest novelty at the beginning of the session, but slightly higher novelty at the end of the session (as compared to the alone condition). Novelty for the first phase of the hybrid condition was in between the group and alone conditions, but it was highest by the end of the session.

Category variety was significantly higher in the alone and hybrid conditions as compared to the group condition. There was a significant main effect of phases. The number of categories explored decreased over time. There was a significant interaction effect on variety. Consistent with the findings of Kohn and Smith (2010), more categories were explored in the alone condition than in the group condition. This result is counterintuitive since it was expected that generating ideas in a group would be more disruptive to the flow of thought and therefore cause participants to jump from one idea to the next instead of continuing to generate more ideas within the same category.

Category variety was expected to be higher in the group phases as compared to the alone phases, regardless of the condition. This hypothesis was not supported. Category variety was significantly different in the alone phase as compared to the group phase both in the hybrid condition and between the alone and group condition. However, the difference was in the opposite direction; the alone phases had higher category variety than the group phases. However, for both the alone and group conditions, category variety declined as the session progressed. But in the hybrid condition, category variety increased in the alone phases that followed the group phases. This suggests that viewing others' ideas helped participants think of more ideas across categories.

The three conditions did not differ in category depth, and depth decreased over time. Category depth was predicted to be higher in the alone phases as compared to the group phases, regardless of condition. This hypothesis was partially supported since category depth was higher in the alone phases as compared to the group phases, but only in the hybrid condition. The same was not true when the alone and group condition were compared. Similar to the trends seen for category variety, category depth declined for alone and group conditions. But within the hybrid condition, the alone phases showed more category depth than the group phases as expected, suggesting that participants in the hybrid condition were able to dig deeper within a category when they worked alone as compared to working in a group.

It was expected that the hybrid condition would have the highest novelty since participants in that condition would be able to utilize both, flexibility and persistence pathways. A mediation model was used to test if there were differences in the processes used to generate novel ideas across conditions. Persistence and creativity were the two

processes assessed based on the dual-pathway model of creativity (De Dreu et al., 2008). It was expected that the hybrid condition would be able to generate more novel ideas using both the flexibility and persistence pathways. Since the independent variable was multi-categorical the results were interpreted using the alone condition as the control. Persistence and flexibility both predicted novelty relative to the alone condition. The hybrid condition did not significantly predict persistence or flexibility as compared to the alone condition. But the group condition significantly predicted flexibility relative to the alone condition. Novelty was not the highest in the hybrid condition and both indirect effects (flexibility and persistence) were not significant; therefore, the hypothesis was not supported.

Individual Difference Variables

Personality factors. Based on the results of Bolin and Neumann (2006) it was expected that openness to experience would positively predict quantity. The results were in the expected direction but openness did not significantly predict quantity and condition did not moderate this relationship. Bolin and Neumann (2006) used groups of four, whereas this study used groups of three. However, both studies used the openness data by aggregating it to the group level. But Bolin and Neumann (2006) measured openness using the NEO-FFI, whereas the BFI was used in this study. The BFI has internal consistency of .83 for the openness subscale, which is higher than that .76 for the NEO-FFI (John et al., 2008). It is possible that some of the difference in results could be due to the different measures used. However, openness significantly predicted category variety. Groups who had a higher mean score on the trait explored more categories than those who had a lower mean score. It seems that high openness allows participants to explore

newer categories even though it may not be related to quantity. It might be possible that the relationship between openness and quantity might also depend on a third variable. That is, in order to explore multiple categories one must be open to experience. Yet, to generate more ideas one might also need to explore each of those new categories systematically. Generating one idea per category may not lead to an increase in quantity but will increase variety. Staying focused and organized in order to generate multiple ideas per category might require other traits, like conscientiousness.

It was predicted that lower openness would predict lower variety, especially in the alone condition since the participants in this condition received no stimulation from the other participants. Openness significantly predicted variety in the expected direction, but the effect was not moderated by condition. Therefore, the second hypothesis was partially supported. Receiving ideas from other group members should provide an opportunity to view more categories and explore them. However, there was no difference between the conditions suggesting that they may not have been open to the ideas generated by others, and therefore did not explore more categories.

Higher scores on perspective taking were expected to yield more ideas, especially in the hybrid and group conditions. But PTS did not significantly predict quantity and there was no moderation. The third hypothesis was not supported. It was expected that participants who were better at perspective taking would be able to generate more ideas by taking the perspective of other group members and building on their ideas. Even though perspective taking did not predict quantity directly, it is possible that the effect is mediated through a third variable, like building on ideas. For this series of studies, it was

not possible to estimate a measure for combination or building on ideas since the ideas were not time stamped.

Alternative predictions were made about the effect of extraversion on quantity. It was expected that higher scores on extraversion would predict higher quantity, especially in the hybrid condition. It was also predicted that extraversion would positively predict quantity regardless of condition. The results showed no significant effect of extraversion on quantity and no evidence of moderation. Both hypotheses 4a and 4b were not supported. Putman (2001) found that extraversion predicted quantity regardless of the type of brainstorming (alone or group). Participants in her study were asked to generate ideas verbally. Verbal expression may be more influenced by extraversion than written expression of ideas. Additionally, the sessions were videotaped. It is likely that those who were high on extraversion found it easier to express themselves on videotape than those who were not. Jung et al. (2012) found that extraverts generated the most ideas when provided with moderate stimulation. They used an electronic brainstorming technique and experimentally controlled the number of ideas participants would see during the session. It is important to note that although the computer-mediated paradigm simulated a real group, data were only analyzed for the individual participant (i.e. data was analyzed at the individual level). In the present study, data was analyzed at the group level, and it is likely that some of the variance was lost in the process. Reanalyzing the data at the individual level may help shed some more light on these results.

Working memory. Being able to hold stimuli in memory while trying to generate new ideas should be an essential part of brainstorming, especially when done with other group members. Those who can hold a previously seen idea in memory while trying to

generate their own could benefit from the stimulation provided by the previously seen idea. Participants who are able to hold ideas in mind, while reading others should also suffer less productivity loss. In this study working memory was measured using three automated tasks – the RSPAN, the OSPAN, and the WCST. The RSPAN measures the ability to read and comprehend sentences while holding previously seen stimuli in memory for later recall. It was expected that higher scores on the RSPAN would predict higher quantity and this would be especially true in the hybrid and group conditions. But there was no significant relationship between RSPAN and quantity even though the results were in the expected direction. One possible explanation could be the difference between the stimuli participants had to remember for the RSPAN task versus the brainstorming task. In the RSPAN, the task is to remember a string of alphabets while examining sentences. For the brainstorming task on the other hand, the information participants had to retain and the information they assessed was very similar (sentences/phrases/words about the same topic). Therefore, there was more overlap between the stimuli and their own ideas as compared to the stimuli and the sentences shown on the RSPAN. This could have made the brainstorming task more difficult even for those who scored higher on the RSPAN.

The relationship between OSPAN and novelty was predicted to be mediated by persistence but not flexibility based on previous research by De Dreu et al. (2008) and De Dreu et al. (2012). Contrary to the predictions, there was no indirect effect of OSPAN on novelty. OSPAN did not significantly predict persistence or flexibility. However, the direction of the relationships was interesting. The relationship between OSPAN and persistence was in the expected direction (positive), but the relationship with flexibility

was negative. De Dreu et al. (2012) found no significant relationship between OSPAN and flexibility, but the reported beta was .12. The results from this study showed a beta of -.09 (see Figure 9). The De Dreu et al. (2012) model was only tested on individuals brainstorming alone, whereas this model was tested on groups from all three conditions – alone, group, and hybrid. When the model was tested only for the alone condition, the results more closely mimicked those of De Dreu et al. (2012). OSPAN still did not significantly predict persistence or flexibility, but both relationships were in the positive direction (Figure 10). Part of what OSPAN measures is the ability to screen out stimuli. In the alone condition, participants did not receive any external stimuli; therefore, there was a lower probability of them becoming distracted and jumping from category to category even if they had lower working memory capacity.

A key difference in results across the two studies was the size of the estimates from OSPAN to the mediators. Even though both were not significant, the results of the present study showed that the estimate for OSPAN to flexibility was higher than the estimate from OSPAN to persistence. Additionally, for the alone condition flexibility did not significantly predict novelty. There were a few important differences in methodology between the current study and the De Dreu et al. (2012; Experiment 4) that could have led to these differences in the size of the estimates. The De Dreu et al. (2012) study analyzed the data at the individual level and participants generated ideas only for 16 minutes. The present study aggregated the data to the group level and the participants brainstormed for 40 minutes. One possibility is that aggregation to the group mean reduced the variance. Testing the data at the individual level may yield different results. It is also possible that time plays a moderating role. The effect of working memory may

stronger earlier in the session than later. We know that more ideas are generated in the beginning of the phase than towards the end. Higher working memory may help participants deal with this large volume of information that is available in a short time. As the session progresses, the amount of information also declines and becomes more manageable, thereby reducing the role of working memory capacity.

The results tell a different story when the path model is analyzed only for the hybrid condition. The relationships between OSPAN and both mediators were negative, but OSPAN only significantly predicted flexibility. Lower scores on the OSPAN led to higher flexibility and the indirect effect of OSPAN on novelty via flexibility was significant. If higher scores on the OSPAN help participants focus and dig deeper within a category, it is possible that lower scores lead to a less systematic approach of idea generation, i.e. jumping from one association to the other, but only if external stimuli are present. However, higher scores on the OSPAN were associated with lower persistence (not significantly). This may be because those who had higher working memory were able to recall the ideas they had seen in the group phases and generate ideas within a large number of categories during the alone phases. The alone phases may have provided an opportunity to recall stimuli that were previously seen.

In the group condition, OSPAN did not significantly predict the mediators and the estimate was positive for persistence, but negative for flexibility. Both mediators significantly and positively predicted novelty, but there was no mediation. As in the hybrid condition, participants in the group condition received external stimulation from other group members. However, in the group condition participants were dealing with stimulation throughout the 40 minutes. The stimulation was most likely higher in the first

part of the session than the second part, given that quantity declined over time. It is likely that participants who had higher working memory were able to screen out others' ideas and generate more ideas within categories. But those who had lower scores on the OSPAN were more likely to get distracted by others' ideas and generate ideas across different categories.

The relationships between the scores on OSPAN and the variables in the dual-pathway model seem to be anything but straightforward. In the hybrid condition, category depth did not significantly predict novelty, but significantly predicted flexibility. The opposite was true for the alone condition in this study. The path analysis for the group condition showed that both flexibility and persistence predicted novelty. The variations in these relationships indicate that different processes are being used in different conditions. Scores on OSPAN were also associated differently with the mediators depending on the condition.

Using the same dual-pathway model it was expected that a higher ability to shift set as seen from the scores on WCST would be related to higher novelty and the flexibility pathway would mediate this relationship. This hypothesis was partially supported as the results indicated that scores on the WCST significantly predicted novelty via the flexibility pathway. However, the indirect effects were not significant for the hybrid and group conditions. The number of perseverative errors was used to indicate 'set-shifting' ability. Fewer perseverative errors indicate a tendency to shift set easily. Higher perseverative errors did not significantly predict persistence, but the relationship was in a positive direction. Lower perseverative errors predicted flexibility, and the relationship was marginally significant. Both persistence and flexibility significantly and

positively predicted novelty. The model based on all the groups across conditions showed a marginally significant indirect effect of the WCST on novelty via flexibility.

Participants who had fewer perseverative errors on the WCST were able to shift set and explore more categories, thereby increasing novelty.

When the model was tested only using the alone condition, WCST still negatively predicted category variety. There was also a significant positive relationship between persistence and novelty. However, flexibility did not predict novelty in this model. This is similar to the trend in the model with OSPAN for the alone condition. Those with lower perseverative errors explored more categories than those with more errors. But the participants in the alone condition were not exposed to other's ideas and were less likely to be distracted. Therefore, those with lower perseverative errors explored more categories, but because they were in the alone condition they could explore each category more deeply, leading to novelty.

In the hybrid condition, the only significant path was from category variety to novelty. Again, similar to the findings with the OSPAN model, category depth did not significantly predict novelty for this condition. The relationships between WCST and the mediators were in the expected directions, but both were not significant. Scores on the WCST did not significantly predict persistence or flexibility for the group condition, but both mediators significantly predicted novelty. The only inconsistency in this model was the direction of the path from WCST to persistence. Even though this path was not expected to be significant, a negative relationship does not make intuitive sense. Participants with higher perseverative errors should be able to stick to one category and explore it deeply before moving on. The negative relationship indicates that higher

perseverative errors led to lower persistence and this negative relationship is only seen in the group condition. Participants had to constantly shift between writing and reading ideas in the group condition. Those who were worse at set shifting may have found this task more difficult and could have endured more production loss. In the alone condition there was no need to shift from reading to writing and in the hybrid condition, the group phase occurs for less than half the total time of the session. This time to work alone in the other two conditions may have allowed those with lower set-shifting ability to generate more ideas within categories as compared to those with lower set-shifting ability in the group condition. Overall, number of perseverative errors made on the WCST significantly predicted novelty of ideas via flexibility when all groups were analyzed together. This suggests that the ability to shift set plays a role in generating novel ideas but the processes used to generate these novel ideas varied across conditions.

Chapter 4

General Discussion

The three studies in this paper shed some light on the benefits of using a hybrid brainwriting paradigm over the traditional options. The first study compared two kinds of hybrid procedures to individual brainstorming. One hybrid procedure started with a group phase (GAGA), while the other started with an alone phase (AGAG). The hybrid condition that started with the alone phase generated the most number of ideas but when compared to the second hybrid condition, the difference was not significant. However, the AGAG condition was significantly better than the alone condition, but the GAGA was not. This finding indicated that there was some benefit in starting the session alone possibly due to the reduction in productivity loss. There were two problems with the methodology of this study. The first was that both the hybrid groups received practice but the nominal groups did not. Therefore, the number of ideas in the first phases of the AGAG and alone conditions should have been similar, but they were significantly different. The second problem was that participants in the nominal group were not always in the same room at the same time, but those in the hybrid conditions were.

To correct for these issues, the second study was designed. All groups were given a group practice session and all members of a group were in the same room at the same time. A traditional group brainwriting condition was added as an additional control. The difference between the hybrid and group condition was significant, with more ideas being generated in the hybrid condition. There were no significant differences between the alone and group conditions, which was consistent with some previous research (Goldenberg et al., 2013). The hybrid condition led to more ideas than the alone

condition, but the difference was not significant. During the individual brainstorming phases, all participants generated ideas in the presence of other group members. One problem with that methodology was that participants could see other people generating ideas, and this could have motivated them to continue generating ideas.

Partitions were used in the third study to ensure that participants were unable to view the ideas of other group members during the individual brainstorming phases. If viewing ideas from other group members had an effect on quantity in study 2, then being unable view the ideas in study 3 could cause a reduction in the number of ideas of the individual brainstorming phases. The third study included the same the conditions (alone, hybrid, and group) as study 2 with the exception of the GAGA condition and the results were consistent with those of study 2. The hybrid condition (AGAG) led to significantly more ideas than the group condition. But the difference between the hybrid and alone condition was not significant. Isolating the participants during the individual brainstorming phases did not seem to affect quantity. The alone and group conditions were also not significantly different from each other. In the third study, a fifth 8-minute phase was also added to the brainstorming session across all conditions to allow more time for the decline to occur. Yet this additional time was not sufficient to generate a significant difference. However, in the last phase of the brainstorming session, the difference between the hybrid and alone conditions was marginally significant.

The studies consistently show that the hybrid condition leads to significantly more ideas than the group condition. The hybrid condition also generated more ideas than the alone condition, but these differences were not significant. There were also no significant differences between the alone and group conditions. The effects of condition on quantity

are discussed below by examining the group and hybrid conditions in comparison with alone condition.

Alone versus Group

Paulus and Dzindolet (1993) found that the difference between the alone and group conditions reduces over time. Similar results were found by Diehl and Stroebe (1991). The present data showed that none of the five phases in the alone condition were significantly different from those in the group condition. The alone condition did have slight higher quantity in all phases but this difference was not significant.

An important distinction between the studies that found an interaction between time and condition and the current study is that their sessions were shorter. The session time was 20 minutes in the Paulus and Dzindolet (1993) study and 16 minutes in the Diehl and Stroebe (1993). The current study examined a 40 minute long session. The alone condition in the present study has also not shown the same degree of decline in performance over time in accordance with previous research (Paulus & Dzindolet, 1993). In a 25-minute session, Paulus & Dzindolet (1993) saw a 79% decline in ideas from the first five minutes to the last five minutes in the alone condition. In the first study presented in this paper, the decline in ideas was 25% from the eight minutes to 24 minutes, and in the second study it was 35%. It is possible the interaction between the alone and group conditions is only visible early in the session. The first session in the present study had significantly higher quantity than all the other sessions for both the group and alone conditions. But as the session progressed these differences in quantity between the alone and group condition became smaller. A repeated measures ANOVA was used to test if there was an interaction between the alone and group conditions using

only the first two phases. The results showed a marginally significant interaction effect, $F(1, 58) = 3.599, p = .063, \eta_p^2 = .058$. These results indicate that the interaction is only apparent in shorter sessions. In longer sessions, the pattern of idea generation in the alone and group conditions does not seem to differ significantly.

Hybrid versus Alone

The hybrid condition led to a higher quantity of ideas than the alone condition in Study 1, but in studies 2 and 3 this difference was not significant. . The alone condition generated ideas for 40 minutes without any distractions. The hybrid condition had 24 minutes of individual brainstorming. The remaining 16 minutes were in a group session where the time was divided between reading and writing. Controlling for the amount of time spent only generating ideas (rate of ideas) might reveal a significant difference between the two conditions. A previous study using EBS showed that when comparing rate of ideas the hybrid paradigm led to significantly more ideas than the alone paradigm (Korde, 2012). Since brainwriting was used in this study there were no timestamps on the ideas. Also, the reading time was not separated from idea generation since group brainwriting phases were used. One way to test this in the future would be to use a yoking method. In the yoked hybrid condition participants would be shown the same ideas that the regular hybrid condition saw during the group phases, but the reading and idea generation would be timed separately (alone – read, generate – alone – read, generate and so on).

Stimulation versus Distraction

As previously noted, the hybrid condition consistently produced more ideas than the group condition. Therefore, there is a need for participants to generate ideas alone

after receiving stimulation to utilize it effectively. Participants in the group condition were able to see ideas from other group members throughout the whole session, but they did not have enough time to reflect on these ideas and generate more. They had the benefit of stimulation, but also the disadvantage of distraction. The participants in the alone condition were not distracted and generated slightly more ideas than those in the group condition, even without the potential additional stimulation provided by exposure to other ideas. Both of these results indicate that both the lack of distraction and the presence of stimulation can increase idea generation. The hybrid condition leads to the most number of ideas and the benefit of both these factors is evident in the alone phases that follow the group phase. Without the stimulation that these participants receive from the group phase, the quantity would decline steadily just as it did in the alone condition. During these alone phases, the participants are able to generate ideas without being distracted.

Individual Difference Variables

Many of the individual difference measures used in the study were exploratory. Few studies have tested the effects of personality variables and working memory on brainstorming. Interestingly, the present study did not find results consistent with previous research. Extraversion was not significantly related to the number of ideas generated, and neither was perspective taking nor openness. However, openness significantly predicted variety. Participants who were high on openness explored more categories and this finding was consistent across conditions. The more open to experience people are the more likely they may be explore ideas that belong to varied categories. The relationship between openness and quantity may not be so straightforward. Openness

may allow the participant to entertain unusual ideas but may not lead to an increased number of ideas. Other factors such as intrinsic motivation and/or conscientiousness may have more of an effect on quantity. Extraversion, on the other hand, could help with talking more in social situations. Therefore, one could assume that extraverts would generate more ideas. However, being more motivated to meet other group members and talk with them is not the same as trying to generate more ideas. Also, writing down ideas may not be as interesting to an extravert as verbally discussing them with other group members. Given the differences in results among various studies, it seems that these personality variables may have different effects on brainstorming depending on multiple factors such as the type of paradigm used (verbal or written), the presence or absence of other group members (alone, group, or hybrid), the length of the sessions, and of course whether the data are analyzed at the individual level or the group level.

Unlike the personality variables, the working memory scores on some of the scales used in this study had different effects on different conditions. The reading span did not have a significant effect on quantity. But the operational span and set-shifting ability (as measured by the WCST) affect novelty differently for each condition. Both of these measures, the OSPAN and the WCST, provided insight into the processes involved in different types of brainstorming. Lower working memory capacity seems to be useful for exploring multiple categories, especially if participants were distracted by the ideas of other group members. Higher set-shifting ability had an indirect effect on novelty through the flexibility pathway, but the relationship was not significant when examined separately for each condition.

These findings highlight that different processes (persistence or flexibility) are utilized during different brainstorming conditions. The findings reported here are based on the brainwriting paradigm. The results could have been different if verbal or electronic brainstorming had been used. Additionally, multi-group analysis was used to test the hypotheses, which requires large data sets. These were conducted only on a cell size of 30 and should be interpreted with caution.

Overall, the studies show a clear benefit of the hybrid condition over the group condition, and a slight benefit over the alone condition. Condition did not affect novelty, but novelty did increase as the sessions progressed. However, there is still much to learn about the hybrid process. These findings suggest how complex this seemingly simple process can be. With decades of research on brainstorming, we still do not know the ideal way to divide our time in a brainstorming session. Based on the results of these studies, we know that starting a session alone may be more beneficial than starting the session as a group. Providing some time to generate ideas alone after a group session is critical and helps generate more ideas. The hybrid condition leads to more ideas than the alone condition even with less time dedicated solely to writing the ideas. This indicates that the hybrid condition somehow allows participants to compensate for the lost time by utilizing the stimulation they receive in the group phases. In future studies it would be of interest to determine under what conditions the hybrid process would lead to more ideas than the solitary ideation process. Using considerably longer sessions and problems for which it is more difficult to come up with new ideas or categories of ideas may allow for greater benefit of hybrid ideation.

With the present data a multilevel analysis would be useful to examine the effects of the individual difference variables on brainstorming. The multilevel analyses would be exploratory and hence, were not performed as part of this dissertation. It is not clear how variance within groups would affect idea generation. For example, if a group consisted of two members who were high on openness and one low on openness or vice versa, how would that affect the number of categories explored? We are still unclear about the effects of personality variables on idea generation even during individual brainstorming. But examining the data from a multilevel perspective would help us understand these relationships better, especially in group situations. Dispersion analyses could be another way to examine the effect of within group variance of an individual difference variable on brainstorming outcomes. A latent growth model would also be of interest to examine the effects of these variables over time.

Appendix A

Figures

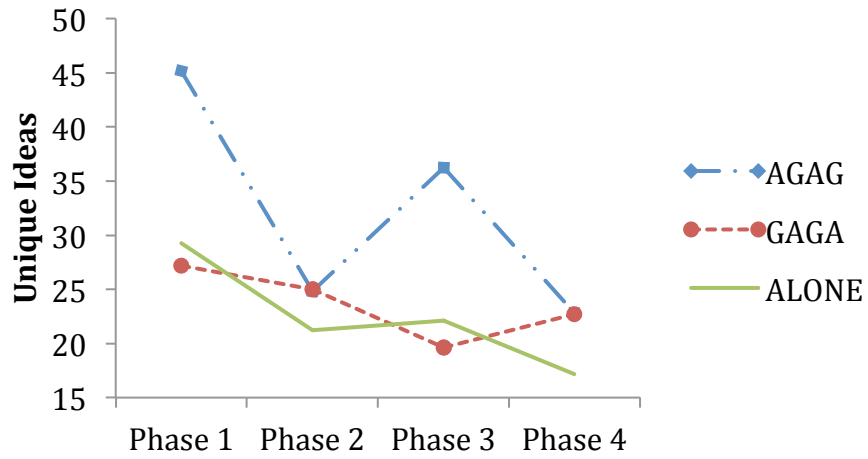


Figure 1. Number of unique of ideas generated in the different conditions across phases in Study 1.

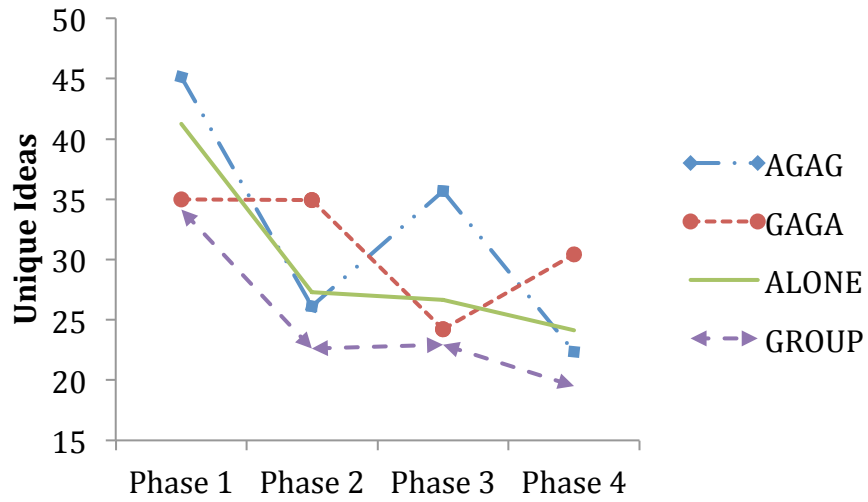


Figure 2. Number of unique of ideas generated in the different conditions across phases in Study 2.

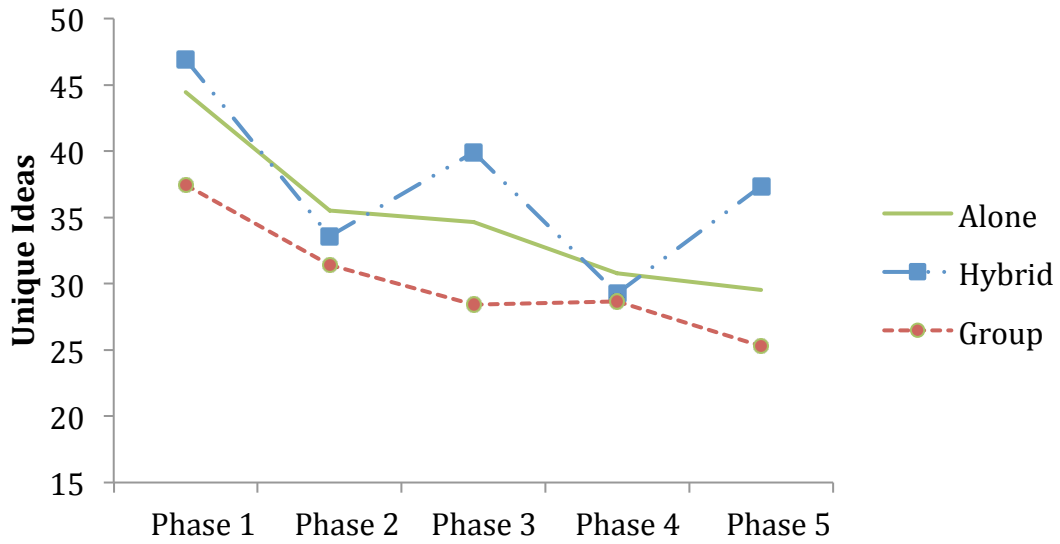


Figure 3. Number of unique of ideas generated in the different conditions across phases in Study 3.

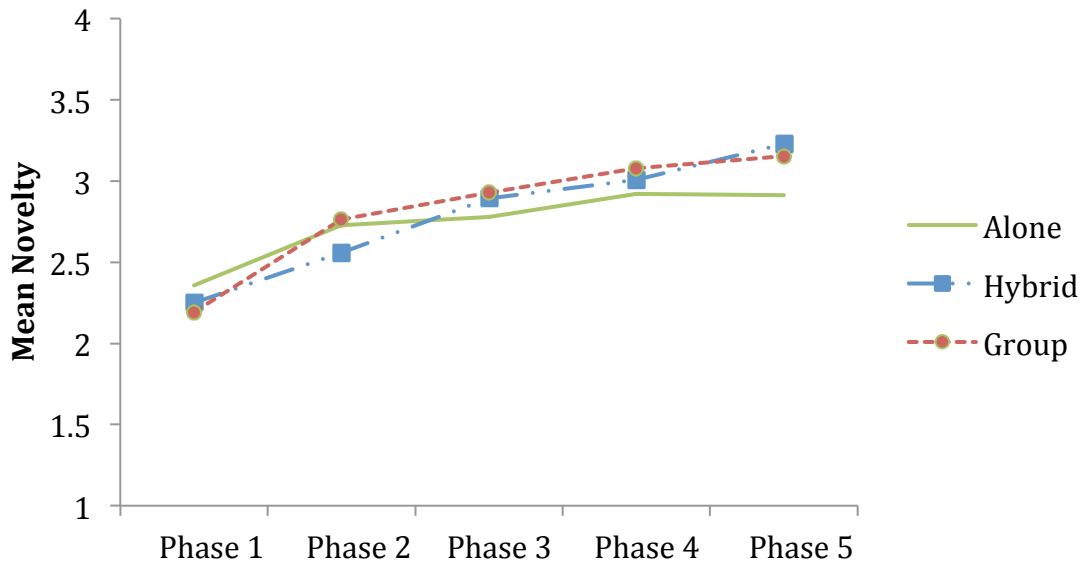


Figure 4. Average novelty of ideas generated in the different conditions across phases in Study 3.

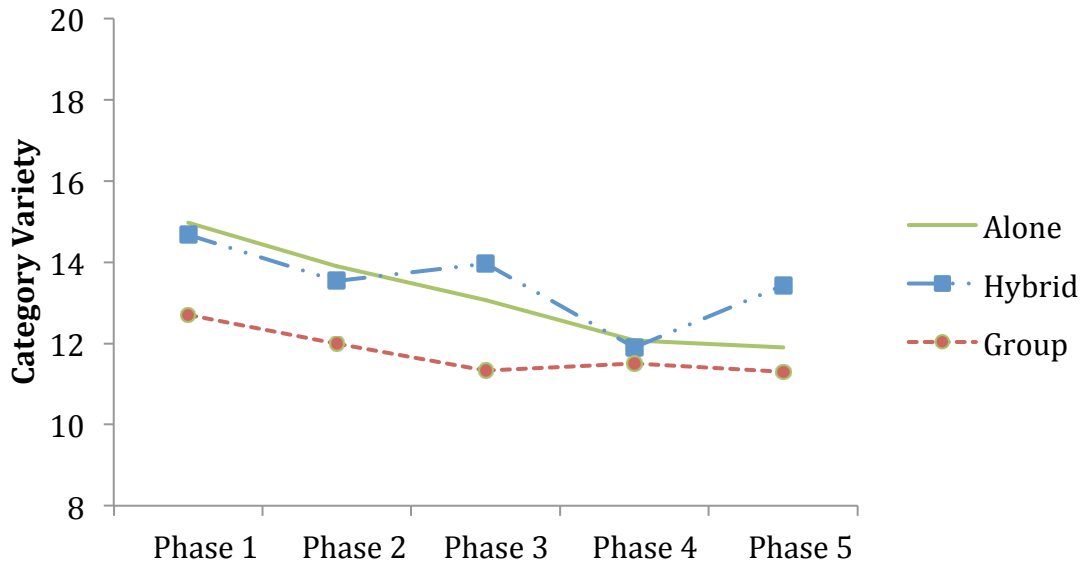


Figure 5. Number of categories explored in the different conditions across phases in Study 3.

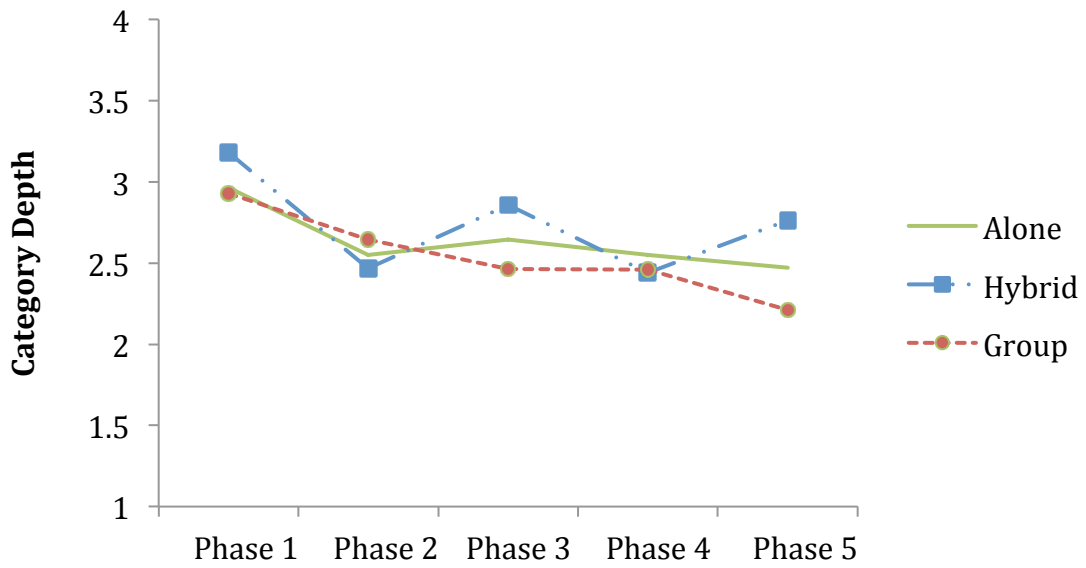


Figure 6. Number of ideas explored per category in the different conditions across phases in Study 3.

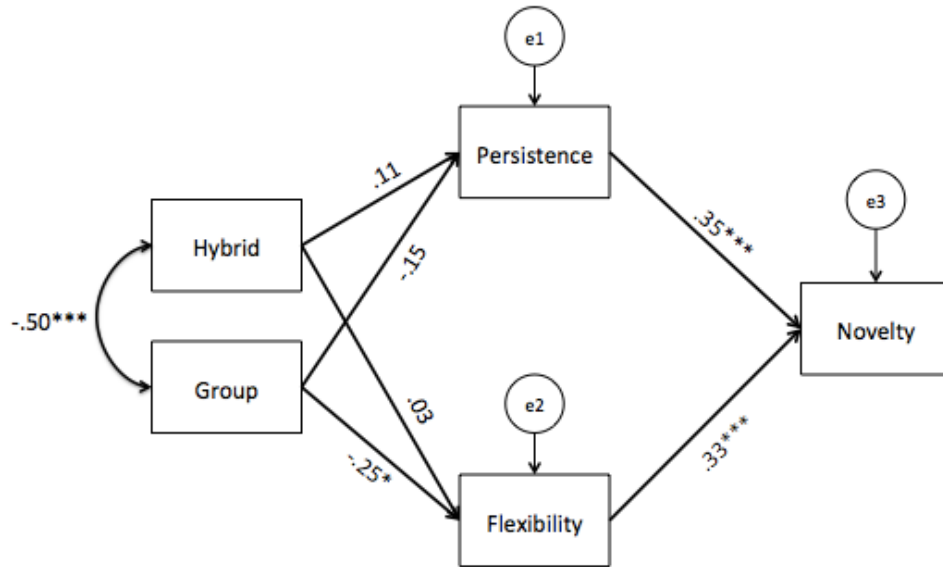


Figure 7. Effect of condition on novelty using the dual-pathway model. The model shows the effect of the hybrid and group conditions as compared to the alone condition.

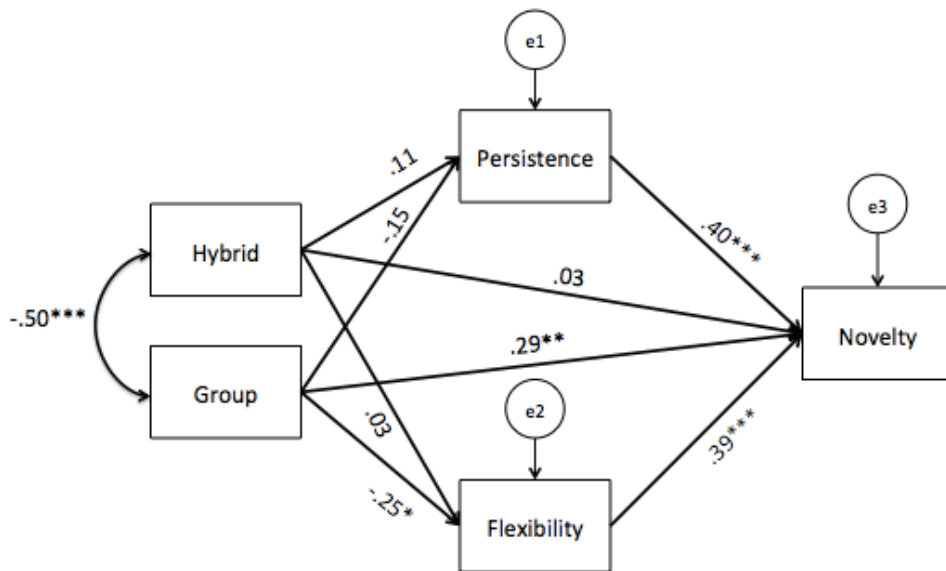


Figure 8. Effect of condition on novelty using the dual-pathway model with direct paths. The model shows the effect of the hybrid and group conditions as compared to the alone condition.

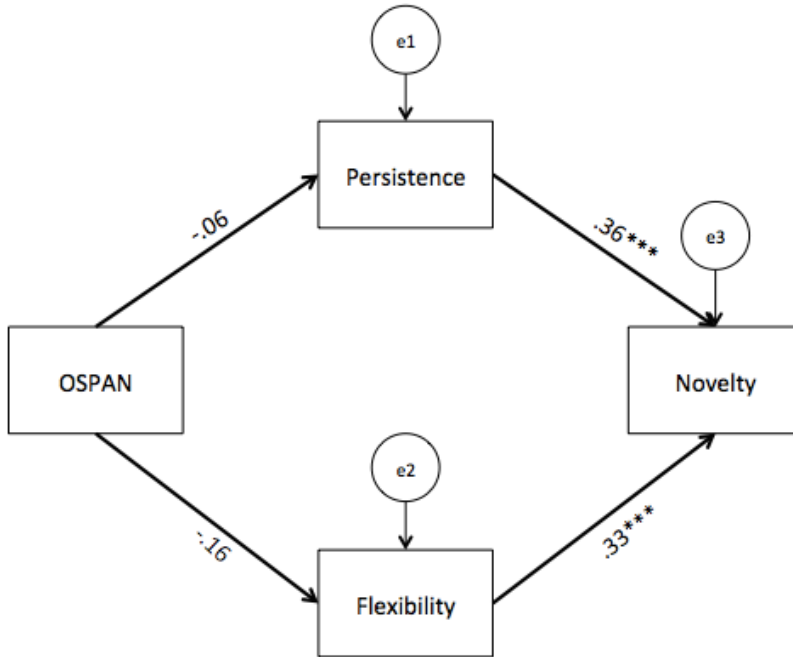


Figure 9. Base mediation model with OSPAN as the predictor using groups from all conditions

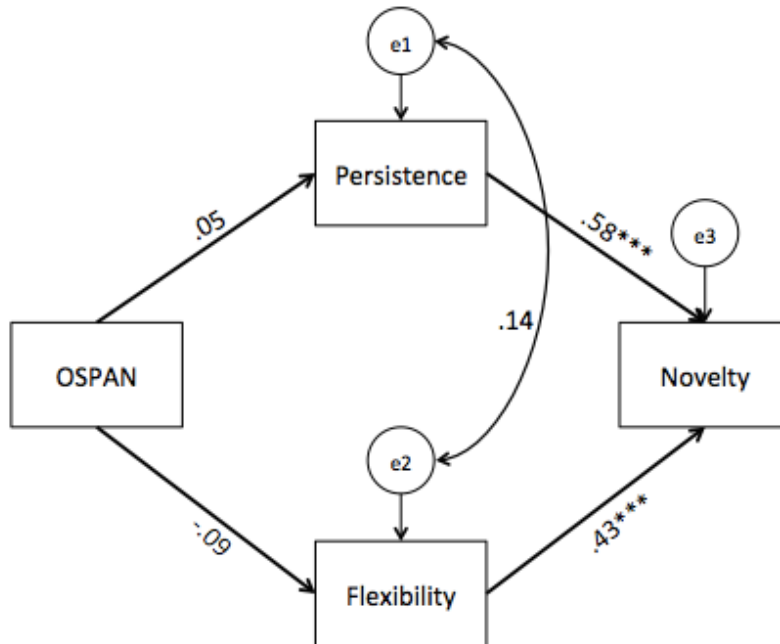


Figure 10. Mediation model with OSPAN as the predictor and with correlated errors. Data from all 90 groups were used.

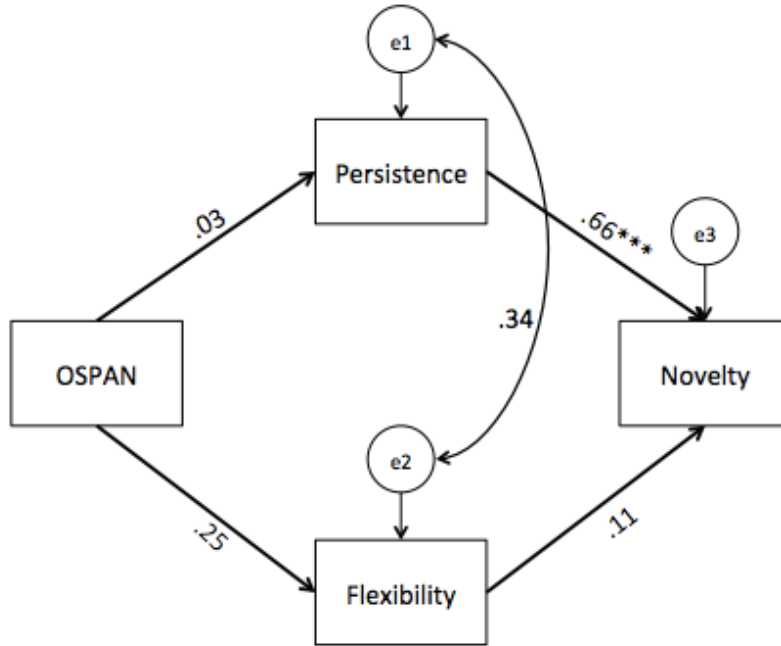


Figure 11. Mediation model with OSPAN as the predictor and with correlated errors. Data from 30 groups in the Alone condition were used.

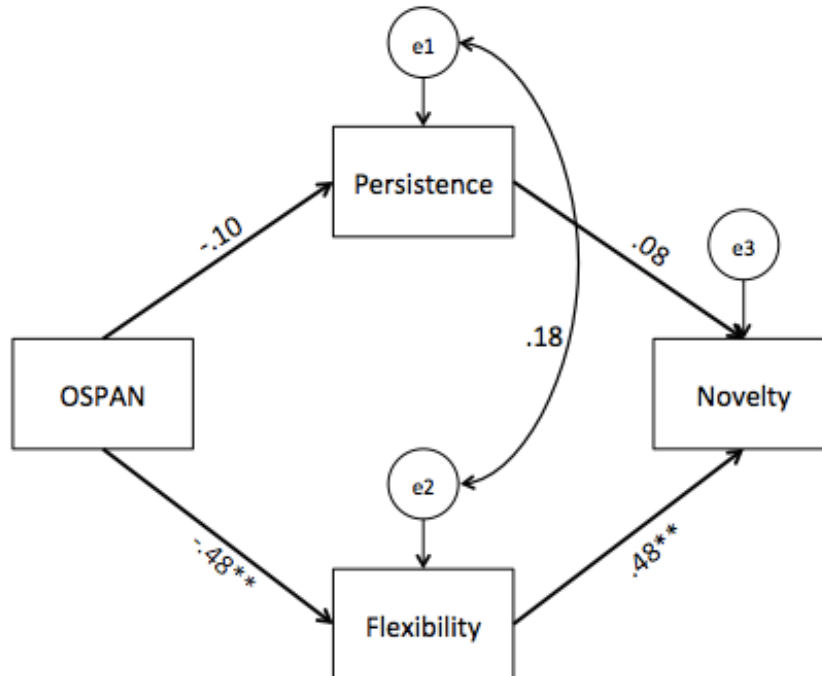


Figure 12. Mediation model with OSPAN as the predictor and with correlated errors. Data from 30 groups in the Hybrid condition were used.

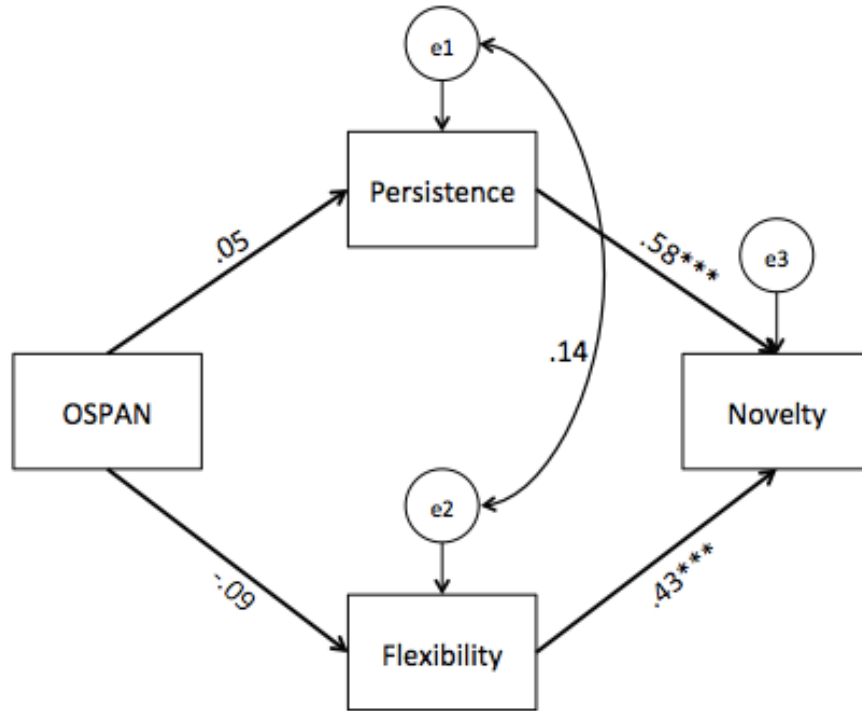


Figure 13. Mediation model with OSPAN as the predictor and with correlated errors. Data from 30 groups in the Group condition were used.

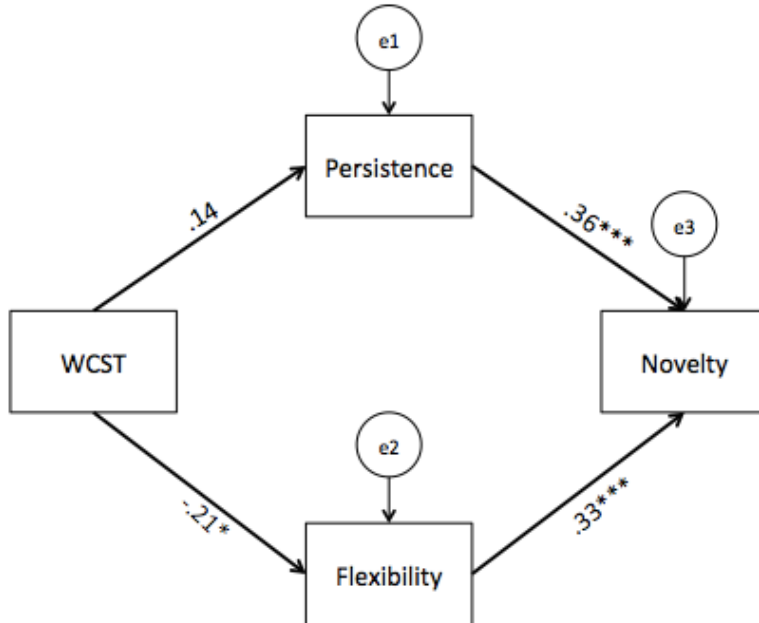


Figure 14. Base mediation model with WCST as the predictor using groups from all conditions

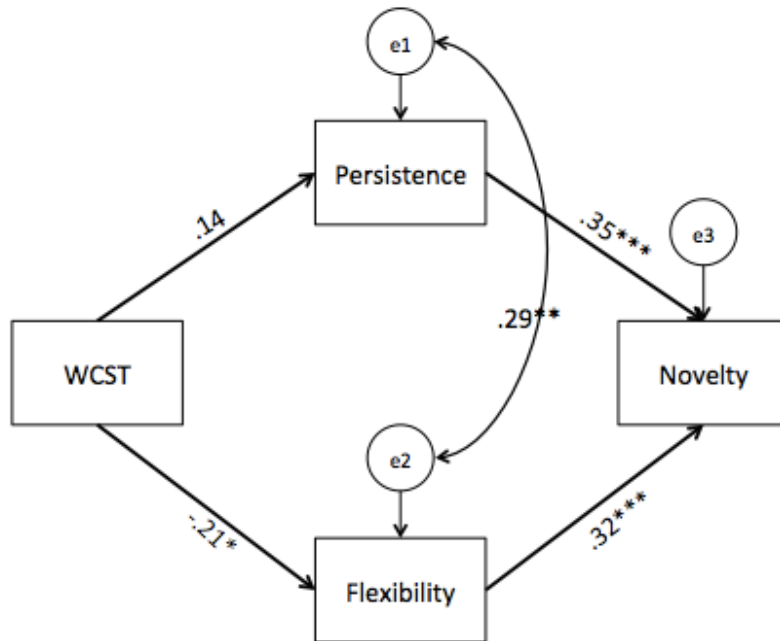


Figure 15. Mediation model with WCST as the predictor and with correlated errors. Data from all 90 groups were used.

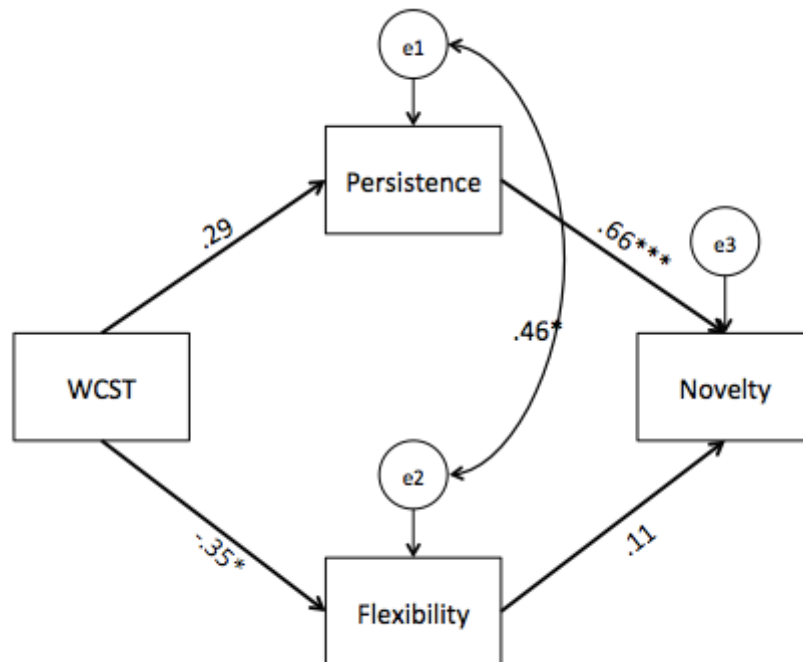


Figure 16. Mediation model with WCST as the predictor and with correlated errors. Data from 30 groups in the Alone condition were used.

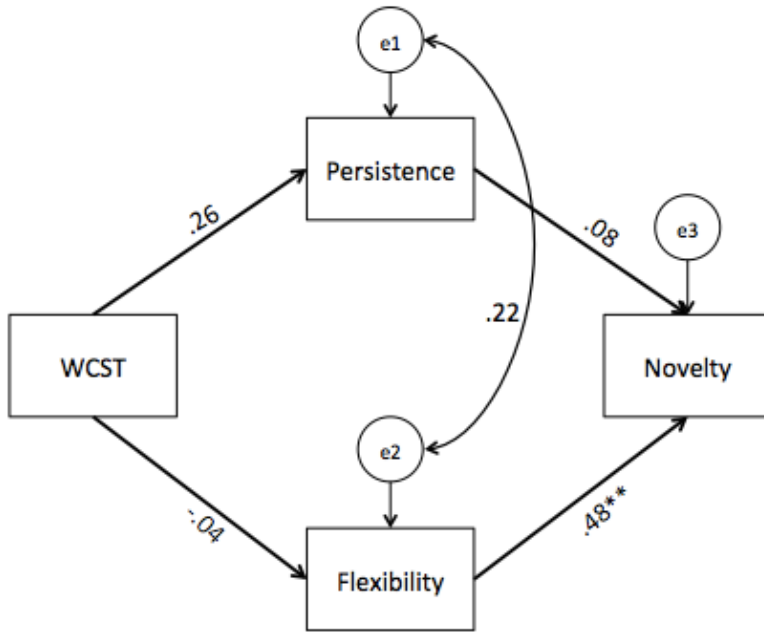


Figure 17. Mediation model with WCST as the predictor and with correlated errors. Data from 30 groups in the Hybrid condition were used.

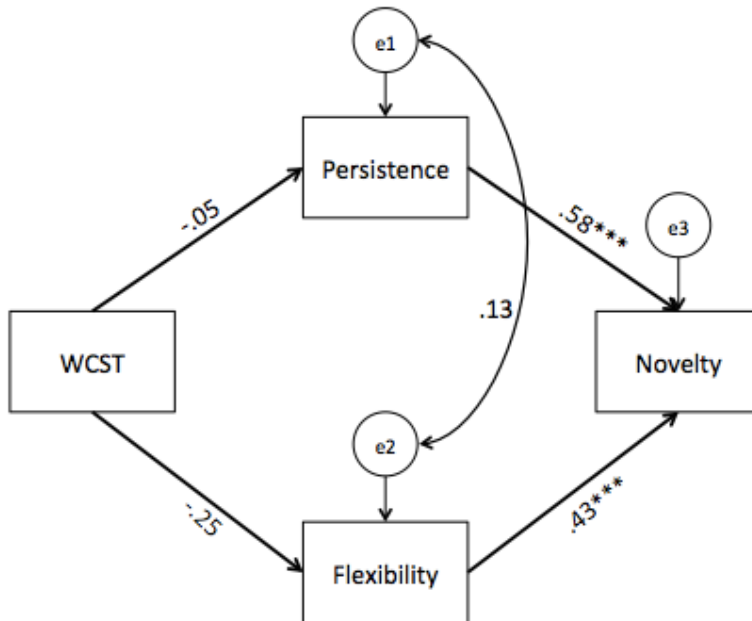


Figure 18. Mediation model with WCST as the predictor and with correlated errors. Data from 30 groups in the Group condition were used.

Appendix B

Tables

Table 1

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

<u>Phase</u>	<u>Alone</u>	<u>AGAG</u>	<u>GAGA</u>	<u>Overall</u>
Phase 1	29.250 (6.032)	45.170 (16.469)	27.200 (12.426)	34.265 (14.565)
Phase 2	21.250 (7.362)	24.830 (8.881)	25.000 (10.760)	23.618 (8.933)
Phase 3	22.080 (6.986)	36.250 (12.621)	19.600 (7.720)	26.353 (11.903)
Phase 4	17.170 (7.334)	22.830 (8.032)	22.700 (9.719)	20.794 (8.520)
Overall	89.750 (25.060)	129.083 (42.451)	94.500 (38.056)	-

Note. Standard deviations (*SD*) are listed in parentheses. There were 12 groups in AGAG and Alone conditions and 13 groups in GAGA condition.

Table 2

Study 2: 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 3

Study 3: 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)
Hybrid				
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.

Appendix C
Experimental Instructions

Experiment Instructions

You are about to participate in a study examining idea generation. In a few minutes you will be given a topic. Your job is to list as many ideas as possible for this topic. These ideas can be as short as a few words. Do not worry about perfect spelling or grammar. You will be writing your ideas on small slips of paper. Please write each idea on a different slip.

When listing ideas to the brainstorming topic, there are some things we want you to keep in mind:

- 1) **Criticism is ruled out.** Adverse judgment of your ideas must be withheld. Write everything you can think of.
- 2) **Freewheeling is welcome.** The wilder the idea the better. It is easier to tame down ideas than to think up. Do not be afraid to write anything that comes to mind. The further out the idea the better. This will stimulate more and better ideas.
- 3) **Quantity is wanted.** The greater the number of ideas the more the likelihood of good ideas. Come up with as many as you can.
- 4) **Build on ideas.** Feel free to combine ideas and build on them to generate more ideas.

When generating ideas, you will be asked to “start” and “stop” several times during the session. Every time you are stopped your used slips will be cleared from the table and you will be given a new pen so we can keep track of when your ideas were generated during the session.

Brainstorming Topic:

Imagine if everyone born after 2013 had an extra thumb on each hand. This thumb would be built just as the present one, but located on the other side of the hand. It faces inward, so that it can press against the fingers just as the regular thumb does now. Here is the question: What practical benefits or difficulties will arise when people start having this thumb?

Please DO NOT start writing until the instructor says START.

Practice Session_C

Topic:

“List as many alternate uses of paper clip as you can”

Please write each idea on a different slip. When you finish writing your idea, **pass it on** to the person on your right. While you are generating ideas, you will receive ideas from the person on your left. If you receive this idea while writing your own, finish writing your idea and then read the one you just received. When you are done reading the idea, pass it on to the next person. Once your own idea comes back to you, place the slip of paper at the **center of the table**.

Please begin writing the ideas on your slips of paper when the instructor says “START”. Try to keep generating ideas until you hear “STOP”.

Practice Session_A

Topic:

“List as many alternate uses of paper clip as you can”

Please write each idea on a different slip. When you finish writing your idea, place it **next to** you and continue generating ideas.

Please begin writing the ideas on your slips of paper when the instructor says “START”. Try to keep generating ideas until you hear “STOP”.

Instructions for Brainstorming

Please generate ideas on the “extra thumb” topic. Again, please write each idea on a separate slip of paper. I would like you to **pass on** the slips to the person on your right. While you are generating ideas, you will receive ideas from the person on your left. If you receive this idea while writing your own, finish writing your idea and then read the one you just received. When you are done reading the idea, pass it on to the next person. Once your own idea comes back to you, place the slip of paper at the **center of the table**.

Please begin writing the ideas on your slips of paper when the instructor says “START”. Try to keep generating ideas until you hear “STOP”. Please continue to follow the brainstorming rules that were previously discussed.

Instructions for Brainstorming_A

Please generate ideas on the “extra thumb” topic. Please write each idea on a separate slip of paper. When you finish writing each idea, place the **slip next to you**.

Please begin writing the ideas on your slips of paper when the instructor says “START”. Try to keep generating ideas until you hear “STOP”. Please continue to follow the brainstorming rules that were previously discussed.

Appendix D
Questionnaires

Date: _____
Time: _____
Slip: _____

A G AG

General Information

Age:.....

Sex:.....

Race:

- Caucasian
- Hispanic
- African American
- Native American
- Asian
- Pacific Islander
- Other:.....

Highest level of completed education:

Current GPA:.....

Appendix E
List of Categories

List of Categories

CODE	CATEGORY	DESCRIPTION
MAT	MATH	Calculation/Math, counting, multiplication tables/tricks, numbers
MUS	MUSIC	better/worse with musical instruments, innovations in music
GAM	GAMES	new games not sports, thumb wars, Puppets, shadow puppets, gaming,
TYP	TYPE	Type/Write/Text is easier/harder/faster, writing instruments
SPO	SPORTS	New sports, two separate sports leagues, disability or advantage, current sports, grip on bats, grip on balls
TAS	TASKS	better/worse at everyday things OR new ways to do everyday things: driving, tying shoelaces (even if it mentions grip), eating, climbing, slapping, punching, multitasking, choking, applying lotion, scratching, pinching, poking, shooting, etc
OCC	OCCUPATIONS	better/worse at certain occupations OR advanced tasks: surgery, construction, plubing, electrical, masssges, waitress/waiter, farming, palm reading, magic tricks, juggling, etc
PRO	PRODUCT	New Products: shirts, gloves, mittens; more hand lotion, more sanitizer, new guns, new mugs, foam fingers, more rings, more tattoos,
GES	GESTURES	Signs/Gestures/Phrases, thumbs up/down, gang signs, high 6s, handshake,
HAN	HAND	back up thumb, poke eyes out, hand turkey, ring finger?, walking on hands, more to wash, middle finger, more fingers to break, extra thumb to suck on, walking on hands, which thumb to use?, 6 finger discount, smart thumb, hand size
ART	ART	Paint/Draw/Craft/Art/Dance
HOL	HOLD	Holding/Grip/Push/Squeeze - utensils, silverware, doors, babies, hands, mugs, cups, etc EXCLUDE BALLS, WRITING INSTRUMENTS and STEERING WHEELS, hold more....,
EXE	EXERCISE	exercise easier/harder, helpful or not, handstand, weights, etc
BEA	BEAUTY	manicures, nails, make up, hair, related expenses, more nail polish, more shampoo
SOC	SOCIAL	bullying/social Discrimination, outcasts, fear, crime, fingerprinting (NOT FINGERPRINTING MACHINES), new race, new culture, abortions, abandon babies, no more reproduction
POL	POLITICAL	take over, a moment in history, political party, wars, government conspiracy,
ECO	ECONOMY	increase/decrease debt, job opportunities, companies will profit/incur loss,
REL	RELIGION	question religion, work of the devil, new religion
TEC	TECHNOLOGY	new cell phones, new keyboards, new tablets, bigger phones, fingerprinting technology/machines, morse code
RES	RESEARCH & EDUCATION	more research, more studies, scientiststs will..., research on genes, DNA, chromosomes, new textbooks, continuing education for doctors/nurses/surgeons etc
HEA	HEALTH	suicide, depression, health problems, arthritis, cancer, need/use surgery, psychological abilities, healthy/unhealthy?, child development, SMARTER, more intelligent, more talented,
ANA	ANATOMY	# of fingers/toes, new names for fingers, more bones, more knuckles, uneven number, wider wrists, more nerves, veins, more neurons therefore more intelligent, mutation, NEW: genes, DNA, chromosomes, etc
SPE	SPECIES	superhumans, aliens, ugly, awkward, 6 thumbed animals, mixed species, animals take over, freak, alien invasions, EVOLUTION
MIS	MISCELLANEOUS	Ideas that do not belong to any of the above categories: doing things fatser/more efficient, generic ideas

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Runa Korde has completed her Doctoral degree in Experimental Psychology from the University of Texas at Arlington. She has worked as a Graduate Research Assistant for Dr. Paul B. Paulus since 2009. Her research has focused on group brainstorming and how different techniques can be applied to reduce the productivity block that groups generally experience. She has a Bachelor of Arts degree in Psychology and a Master of Arts degree in Applied Psychology (Clinical), both from the University of Mumbai, India. She also received a Master of Science degree in Experimental Psychology from the University of Texas at Arlington. She has been working on several different projects with Dr. Paul B. Paulus such as the studies that have been mentioned in this paper as well as other studies related to electronic brainstorming and creativity