When is More Heads Better than One?

Creativity, Quantity and Quality in Idea Generation.

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ABSTRACT

Good user interface design is a problem solving process, where the goal is to produce a design that addresses the user's needs. This process involves generating and iterating solutions. Although idea generation, also known as brainstorming, is a key element to good design, it is unclear how to conduct effective brainstorming sessions. Theoretically, individuals who work together should produce creative and successful solutions. In practice, individuals who work independently produce more ideas or, on average, better ideas than individuals who work together. This study investigated brainstorming in two sessions and in three conditions. In two conditions, participants worked individually in one session and as a group in the other, in a counterbalanced manner. In the third condition, participants worked individually in both sessions. The results indicated that creativity is impaired when individuals brainstorm together in the second session compared to brainstorming together in the first session or brainstorming independently.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PROBLEM SOLVING

Problems and challenges arise in all areas of life and therefore vary widely in topic, complexity, importance and degree of expertise required to solve or overcome. Some problems are easily solved while other problems are not (e.g., what to do when a car is almost out of gas vs. determining the most appropriate information architecture for a web site). When the solution is not readily apparent, an individual must engage in problem solving. Due to the pervasiveness of problems, most individuals will regularly engage in problem solving. It is therefore important to understand how to effectively approach problems to achieve the best possible solution.

The problem solving process occurs in multiple stages, ranging from problem identification, idea generation, idea selection or decision-making to implementation (Hymes & Olson, 1992). *Idea generation* refers to the production of possible solutions to the problem; *idea selection* is the evaluation of solutions that have been produced and the process of choosing the one that best addresses the problem and has the fewest drawbacks. *Implementation* involves testing the solution, allowing time for it to take effect and making adjustments or changes throughout the implementation process (Harris, 1998). An important part of the problem solving process is the production and consideration of *multiple* ideas or solutions. In addition to understanding how the problem solving process occurs it is also critical to understand how *successful* problem solving occurs. Wallas (1926) examined reports of individuals who had been successful problem solvers. Common among these problem solvers was that their solutions were creative. Creative solutions or products are defined as novel and valuable or useful in some way (Gilhooly, 1982). The issue of creativity is discussed later. Wallas (1926) examined the problem solving processes of these individuals for commonalities, and his findings are noted next.

Wallas' Problem Solving Stages

Although problem solving may appear to be a process with predetermined stages (e.g. Hymes & Olson, 1992), the phenomena is not predictable or well understood. Wallas (1926) identified successful creative problem solvers and examined their processes. He noted stages that occurred during the problem solving process and referred to these as *preparation*, *incubation*, *illumination* or *inspiration*, and *verification*. These stages are similar to those identified by Hymes and Olson (1992). During *preparation,* or to use Hymes and Olson's language, during *problem identification* (1992), the individual becomes familiar with the problem and engages in conscious and effortful work towards a solution. This initial work generally does not lead to the final solution but assists in further educating the individual about the intricacies of the problem. Although it is unclear what the individual does during this initial stage or what the outcome is, it most likely involves *idea generation* possibly combined with the interactive *idea implementation.* The information garnered through this process contributes to *problem identification.* Following *preparation,* Wallas (1926) noted that the problem solver takes a period of rest, setting the problem aside and ceasing to work on it consciously. Wallas (1926) did not indicate reasons for the rest period but fatigue, lack of progress or intervening circumstances are possible explanations. Poincaré (1908, as cited by Gilhooly, 1982) hypothesised that unconscious work occurs during this *incubation* phase. Gilhooly (1982), however, speculated that the incubation phase is "a necessary rest period which enabled a later period of conscious work to proceed more effectively than it would have without the break (pp130)." The rest period is concluded when the problem solver has a moment of *inspiration*. The ultimate solution is not realized in its entirety during this moment of inspiration, but the path to its completion is recognized. This stage would therefore seem to involve *idea selection*. Finally, the individual consciously works during the *verification* stage to develop the *inspiration* and arrives at the final solution otherwise known as *idea implementation*. Wallas (1926) offers some suggestions for ways to help encourage *inspiration* and transition into the *verification* stage; however, the process remains highly unpredictable, that is, the point at which the *incubation* stage ends and *inspiration* occurs is undetermined. Additionally, transitioning from one stage to the next does not signify that a prior stage will be abandoned; rather as all stages inform each other, the process is iterative and prior stages may be revisited. It is unknown how this capricious transitioning between stages, or the absence of time restrictions, impacts the production of creative or successful ideas. The formal study investigated only the idea generation component of problem solving because *brainstorming* is an integral part of User Centred Design (UCD) (Maguire, 2001; UPA, 2007), a process employed in software development where stringent deadlines are in place. Furthermore, software development often involves collaboration of non-collocated groups. It is therefore critical to know how brainstorming can be conducted effectively and efficiently: whether groups working together or individuals working independently produce better results. That is, is the time and expense of bringing individuals together to work as a group merited. The issue of individuals working together interactively (in groups) or non-interactively (individually) is considered in this thesis.

CREATIVITY

As noted, the commonality Wallas (1926) found among successful problem solvers was that their solutions were creative. The importance of creativity in product design has been noted among others like Gilhooly (1982) who observed that creative products were not only novel but often proved to be valuable and useful in some way. In other words, creative products provided a solution to a problem. As creativity appears to be an important factor in producing successful solutions to problems, it should be investigated. This was accomplished in the formal study by using creativity as an indicator of the quality of ideas generated in brainstorming sessions. Although understanding the problem solving process of successful and creative *individuals* can assist in identifying and encouraging elements of creativity, it is first necessary to understand what creativity is. Four perspectives of creativity are considered next.

Mednick

Mednick (1962) proposed that creative thinking involves forming useful *new combinations* of ideas. He hypothesized that combinations could occur in three ways: by serendipity, through similarity, or by mediation. Serendipity is the accidental occurrence of environmental stimuli, which inspires the combination of ideas. For example, the accidental contamination of samples with mould led to the discovery that this mould (penicillin) inhibited bacterial growth. Similarity on some dimension, such as rhymes or alliterations, inspires creative combination of ideas. Finally, mediation combines ideas through associations, for example, using a vacuum cleaner to remove flies on a ceiling through the association of ceiling with floor: ceiling – floor – vacuum cleaner (Gilhooly, 1982). Although the focus to this point has been on the creativity of individuals, Mednick's theory of creativity implies that groups, that is, individuals who work together, should be more creative than individuals who work independently, as there are opportunities to combine ideas across members of the group. Therefore, groups should be more successful problem solvers than individuals working on their own.

In an attempt to verify the theoretical advantages of individuals working in interactive groups compared to individuals working alone, in what one may label non-interacting groups, this thesis investigated the problem solving performance of both interacting and non-interacting groups. Group and individual brainstorming performance is discussed later.

Koestler

Like Mednick, Koestler (1964) also defines creativity as the linking together of two (or more) previously unconnected "frames of reference". This involves applying context-specific rules or knowledge in a new context. For example, Archimedes presumably applied his knowledge of water displacement in a bath as a means for measuring volume. Similarly, the use of a desktop metaphor for a computer user interface to help make the capabilities of the computer clear, would have required applying knowledge from an office that uses paper, to a digital context. While Koestler's definition of creativity differs slightly from Mednick's in the sense that Koestler focuses on applying information in a different frame of reference whereas Mednick simply discusses combining information in novel ways, the gist remains the same: creativity involves the novel pairing of information. Thus, Koestler's theory supports the notion that groups should be more creative than individuals alone as each individual can provide different "frames of reference", therefore resulting in more potential opportunities to link unconnected "frames of reference" across individuals.

Gruber

Starting from quite a different theoretical perspective from Mednick and Koestler, Gruber (1980) applied a Piagetian approach to creative thinking. He proposed that the creative process involved assimilation and accommodation. As new information is learned it is assimilated into existing concepts or the existing concepts are modified to accommodate the new information. As with Mednick and Koestler, this theory considers the creative process one in which new ideas are the result of novel combinations, that is, the incorporation of new information with old knowledge. This further supports the advantage of working in groups, as each member may provide new information to the group based on his / her area of interest or study thereby allowing for more opportunities for assimilation and accommodation.

Guilford

Guilford's (1967) concept of creativity also incorporates the notion of combining ideas however he goes beyond this one-dimensional perspective on creativity, saying that creativity is not only the result of combinations or modifications to existing ideas, which he calls "elaboration", but that individuals can be creative by generating many ideas. This is what he refers to as "fluency". Likewise, ideas may arise from a wide variety of domains or categories, which Guilford labels "flexibility". Novel ideas, he refers to as "original" (Paulus, Larey & Dzindolet, 2001). Therefore, according to Guilford, if groups are more creative than individuals, for the kinds of reasons described earlier, groups should generate more ideas, from a wider range of categories. They should also generate a higher number of "original" ideas and provide more opportunities for elaboration and combination of ideas than individuals working alone. In line with Koestler's thinking, groups should be the most creative as different individual perspectives should widen the range of potential ideas emerging.

Creativity was examined in the formal study because of its importance in successful problem solving. While various explanations and definitions of creativity have been provided, they all agree that creativity involves combining ideas. Therefore, combinations was considered the centrally defining characteristic of creativity. However, Guilford's additional categories of fluency, flexibility and originality were also used in the assessment of ideas produced in this study.

Most reviews conclude that creative achievements are the result of *individual* mental activity (Ochse, 1990; Simonton, 1988; Sternberg, 1988). Indeed, it is notable that the social science literature on creativity yields few citations of *group* creativity (Kasof ,1995; Paulus et al., 1999), especially since the above arguments suggested that groups should be more creative than individuals. The possible advantages of working in groups are discussed next.

GROUPS

Many organizations have recently changed their work culture to embrace teamwork. An increase in team-based work was especially seen in the 1990s in both industry and academia (Hogarth, 2001). Hogarth attributes this growth in teamwork to the perception that collaboration can help organizations survive turbulent times. There is a widely held belief that teams outperform individuals (see Paulus, et al., 2001). According to Kelley and Thibaut (1969), for example, working in groups is beneficial because individuals are able to build on the ideas suggested by others and to pool uncorrelated deficiencies. Uncorrelated deficiencies are weaknesses that are not shared by all group members such as lack of expertise in areas of importance. Another advantage of groups is that individuals can catch each other's errors in problem solving (Price, 1985). However, there are other practical advantages to working in groups. For example, teams of people can complete large-scale projects that a single individual could not accomplish alone because they are physically or mentally too demanding (Salas, Dickenson, Converse & Tannenbaum, 1992). This is the case with modern software development, which requires diverse skills and knowledge sets that a single individual could not possess. Thus far the process through which individuals solve problems has been considered. It has been argued that groups should solve problems more effectively and creatively than individuals. One remaining issue is how groups should brainstorm in order to generate, share, combine and develop ideas. The next section discusses brainstorming.

BRAINSTORMING

Brainstorming has become synonymous with idea generation, which, as discussed earlier, has been identified as part of the problem solving process (Hymes & Olson, 1992) and integral to UCD (UPA, 2007). Theoretically, many ideas may be generated in a brainstorming session. This productivity is assumed to be beneficial as the best solution is not always produced first. The production of multiple ideas also prevents the hasty selection of an initial idea at the expense of exploring others, which may prove to be better. As a result, the production of many ideas should lead to more good ideas as the problem solver(s) achieve(s) a better understanding of the problem (Wallas, 1926). The notion that more ideas should result in more good ideas was one of two underlying assumptions when Osborn (1957) introduced the concept of "brainstorming", a process designed specifically to facilitate the generation of *many* ideas. The other assumption was that groups should produce more ideas than individuals, as discussed earlier. Brainstorming was originally conceived of as a verbal process occurring in a group working synchronously, interactively, and face-to-face, to generate numerous and, as far as possible, unconventional ideas.

During a brainstorming session members of a group are typically asked to freely generate as many ideas as possible about a given topic and to share them verbally (Barki & Pinsonneault, 2001). This requirement is based on the principle that deferring judgement increases the number of ideas produced, and on the assumption that quantity breeds quality. Brainstorming sessions are guided by four rules. One is that criticism is not allowed; another that freewheeling is welcomed; the third is that quantity is wanted; and fourth, that combinations and improvements on ideas are sought. Instructions to participants reflect these rules; they are asked to state as many ideas as possible, the wilder or more creative the ideas the better, to improve or combine ideas, and to accept all ideas without criticism and record all ideas for future consideration (Kramer, Kuo & Dailey, 1997).

According to Cooper, et al., (1998) the result of these four rules of brainstorming is twofold. First, individuals are able to concentrate on generating ideas, thereby producing more ideas. This is what Guilford (1967) refers to as *fluency*, as discussed earlier. Second, participants are freed from conventional thinking, thus producing a greater variety of ideas, or what Guilford (1967) refers to as *flexibility*. Inspiration from other group members may also result in unconventional thinking, referred to earlier as *originality* (Guilford, 1967). Osborn also asserted that brainstorming would help groups produce more ideas and a wider range of ideas than individuals would on their own. He encouraged the *combination* of ideas during brainstorming, which was identified by Mednick (1962) as an element of creative problem solving, and which should result in more combinations than those produced by individuals. Thus, Osborn's concepts of quantity and quality appear to incorporate the elements of creativity that Guilford (1967) argued would include *fluency, flexibility, combinations and originality*. This compatibility between Osborn's brainstorming process and Guilford's elements of creativity further supports the use of these elements as measures of quality in the present study. Accordingly, in addition to resulting in a wider range of ideas and more combinations of ideas, brainstorming in groups should also result in higher levels of creativity. Research into brainstorming in interacting and non-interacting groups should thus contribute to understanding group creativity, which researchers like Kasof (1995) and Paulus and his colleagues (1999) argued, represents an important void in the social science literature.

As noted, in this thesis, Guilford's characterization of creativity: *fluency, flexibility, combinations and originality*, were used to measure Osborn's concepts of quantity and quality in order to assess brainstorming performance in interacting and non-interacting groups. To date, the brainstorming research has focused almost exclusively on the quantitative aspect. These studies are reviewed next and a discussion of quality is resumed later.

Assessments of Brainstorming Sessions and Outcomes

Individuals versus Group Brainstorming Performance

As previously noted, Osborn (1957) made two assumptions concerning brainstorming. The first was that the production of more ideas would lead to more good ideas. A review of the brainstorming literature reveals that empirical research has neglected to address and verify this assumption. Instead, the emphasis has been on measuring brainstorming performance quantitatively to evaluate Osborn's second assumption, that groups should generate more ideas than individuals.

Van de Ven and Delbecq (1971) devised a method for comparing the performance of brainstorming groups with individuals. In their study, individuals generated ideas separately and independently. These ideas were recorded and collected from each individual. Next the ideas from different individuals were combined to form one list and any redundant ideas (repetitions) were removed. This list represented the sum of unique ideas produced by individuals who were assigned to a group referred to as non-interacting in this thesis. This process is termed the *Nominal Group Technique* (NGT). It provides a means of comparing individuals in non-interacting groups with interacting groups. Using the output of a group, be it interacting or non-interacting, as the unit of analysis avoids the risk of confounding the results with the number of participants in one group. Van de Ven and Delbecq's (1971) results indicated that brainstorming in non-interacting groups actually produced more ideas than brainstorming in interacting groups. This finding contradicts Osborn's (1957) prediction that interacting groups would be more productive than non-interacting ones. One possible explanation for this finding is that the interaction among individuals in a group actually offers no significant advantage.

Another possibility is that there are problems with the brainstorming process, which primarily impedes group performance (see, e.g., Steiner, 1972). Explanations for the results are considered next.

Ringelmann Effect

The unexpected underachievement of groups is not limited to brainstorming activities. Rather, it has been noted that groups consistently under-perform when engaging in additive tasks. *Additive tasks* require all members of the group to engage in the same activity and combine their efforts such as shovelling snow from a laneway. Idea generation is an additive task, because members of the group engage in the same problem solving activity, namely the production of ideas. Group members combine their efforts to generate as many unique ideas as possible. Although there are other types of tasks, these tasks do not require all group members to engage in the same work to complete the activity and are thus not relevant to idea generation or this study.

With additive tasks there is a discrepancy between the prediction that groups will outperform individuals and the actual findings. It has been termed the "Ringelmann Effect", after the researcher who discovered that the more participants who worked together to pull a rope, the less force each would exert, thereby failing to achieve their additive potential (Hewstone, Stroebe & Stephenson, 1996). If this is the case with brainstorming, then a discrepancy between expected and actual results should be found with different group sizes. The discrepancy between actual and predicted results should increase with group size to the extent that the average number of ideas generated per person would decrease as group size increases.

Evidence for the Ringelmann Effect in Brainstorming. While most brainstorming research has been conducted with relatively small groups of four or fewer members, a few studies have investigated the relationship between productivity in idea generation and group size (Valacich, Dennis & Connolly, 1994). The general finding is that larger groups generate no more ideas than smaller ones (Bouchard, Drauden & Barsaloux, 1974; Bouchard & Hare, 1970; Fern, 1982; Hackman & Vidmar, 1970; Lewis, Sadosky & Connolly, 1975). In contrast, non-interacting groups show a positive and monotone relationship between group size and number of ideas generated (Hogarth, 1978). Accordingly, the superiority of non-interacting groups over interacting groups increases with group size (Bouchard & Hare, 1970; Lewis, Sadosky & Connolly, 1975). Taken together, these studies provide evidence that interacting brainstorming groups are subject to the Ringelmann effect. Steiner (1972) proposed that the brainstorming process inhibited idea generation in interacting groups and thereby caused the Ringelmann effect. The problems Steiner (1972) identified with brainstorming are discussed next.

Process Losses

Steiner (1972) asserted that the discrepancy between expected and actual results could be attributed to what he called "*process losses*", or factors that inhibit performance. Process losses are assumed to be present when groups interact but not when group members work independently (Scudder, Herschel and Crossland 1994), in other words, as non-interacting groups. Furthermore, Steiner (1972) concluded that these process losses could account entirely for the difference between the expected and the actual productivity of the group. From this perspective, actual productivity refers to potential productivity minus the losses incurred by a faulty process, that is, problems that are a direct result of the brainstorming process. Examples of process losses include *evaluation apprehension*, *free riding*, *limited airtime*, *production blocking*, and *cognitive inertia* (Hymes and Olson 1992), which may be due to two kinds of phenomena: *motivation losses* and *coordination losses.*

Motivation losses. Motivation losses occur within an individual. They may be increased by process losses such as evaluation apprehension and free riding. Evaluation apprehension is the fear that other members of the group will evaluate the individual's ideas negatively. As a result, the individual deliberately limits his/her contributions. Perhaps Osborn (1957) had this effect in mind when he developed his brainstorming rule that criticism is out. Free riding occurs when an individual does not maximize their effort to produce ideas and instead relies on other members of the group to contribute. In order to reduce evaluation apprehension, the formal study used similar instructions as Osborn did, which emphasize that criticism is not permitted. Additionally, to combat free riding, participants were instructed that the ideas they alone produce will be examined. Other methods of combating motivational losses will also be employed based on the results of past research. These methods are discussed later (see Modified Brainstorming Procedures).

Coordination losses. Whereas the above notions of evaluation apprehension and free riding are attributed to individuals and collected under the rubric of motivation losses, *coordination losses* are a direct result of process such as *limited airtime, production-blocking* and *cognitive inertia*, irrespective of the individuals involved. It should be noted that it is co-ordination losses rather than motivational losses, that account for the Ringelmann effect in most additive tasks, and that account for the greatest discrepancy between expected and actual productivity with brainstorming (Hewstone, Stroebe and Stephenson, 1996).

One problematic aspect to Osborn's brainstorming process is that it is done verbally, where only one member of the group is allowed to speak at a time. As a result of sharing "airtime", group members can only participate a fraction of the allotted time. Consequently, the output resembles that of a single individual. Consider the following example. If a brainstorming group has four interacting members and they are given 16 minutes to generate ideas, these members should each get four minutes to speak if time is shared equally; that is, each person's "airtime" is limited to 4 minutes. Using non-interactive group brainstorming where participants brainstorm separately, each member could use the full 16 minutes as they are working in parallel. Thus the non-interacting group's results are the product of 16 minutes x 4 = 64 minutes compared to the interacting groups 16 minutes. Although some redundancy of ideas may occur, non-interacting groups using the Nominal Group Technique paradigm would appear to have an advantage over the traditional interacting brainstorming group. Logically, this advantage would grow with larger groups.

L*imited airtime* results in two other types of process losses, namely *production blocking* and *cognitive inertia.* While group members wait to share their ideas, they must hold onto and remember these rather than think of new ones; this is termed *production blocking*. In addition to hampering the production of new ideas, this serial brainstorming process, or turn taking, also prevents the group from pursuing and exploring more varied ideas. This is known as *cognitive inertia.*

In an effort to counteract the Ringelmann effect and minimize process losses in interacting groups, various efforts have been invested in modifying Osborn's brainstorming process. A review of the modifications, which are the most important for this thesis, is presented next.

Modified Brainstorming Procedures for Interacting Groups

While numerous modified brainstorming techniques have been proposed, the Problem Centered Leadership (PCL), the Written Feedback Procedure (WFP), and Electronic Brainstorming (EBS) are most frequently referred to in the literature.

Maier's (1970) PCL attempts to structure the group's interaction by employing a moderator to prevent individuals from dominating the discussion. The moderator can then request ideas from silent members, thereby combating evaluation apprehension and free riding. (S)he can ask critical questions and stimulate conversation in an effort to overcome cognitive inertia, as well as review the problem to ensure that group members understand the critical issues. The present study will employ a moderator to insure that the brainstorming rules are followed, and as such, evaluation apprehension and free riding are reduced.

Madsen and Finger's (1978) WFP allows participants to exchange written copies of their ideas midway through a brainstorming session. Price's (1985) modification to the WFP allows individuals to view the ideas of others throughout the idea generation period. This procedure allows individuals to build on the ideas of others while possibly minimizing the types of process losses associated with full interaction, namely evaluation apprehension, free riding, limited airtime, production blocking, and cognitive inertia. Although interacting groups using the WFP have not outperformed non-interacting groups, performance is typically very similar in the two conditions (Price, 1985). Thus, the WFP combats process losses effectively as these groups perform as well as non-interacting groups. It is important to note that WFP did not exceed the performance of non-interacting groups, and therefore it does not completely eliminate process losses. As a result, brainstorming procedures continue to be modified in an attempt to exceed performance of the non-interacting group. This thesis will require participants to write their ideas on cue cards, in both the interactive and non-interactive phases to assist in reducing process losses.

EBS attempts to eliminate production blocking without sacrificing piggybacking, i.e., building on each other's ideas. The technique uses a computer-based file-sharing procedure whereby each participant types a brief idea or comment, sends the file to a shared pool, and then receives a randomly drawn file containing a brainstorming idea with comments from other members of the group. The participant appends additional comments, returns the file to the pool and receives another randomly drawn file and so on until the session ends (Valacich, Dennis and Connolly, 1994). EBS has been conducted anonymously in the hope of overcoming evaluation apprehension, and non-anonymously to reduce free riding. As with the other modified brainstorming procedures, EBS does result in better performance than traditional brainstorming. While most brainstorming procedures have not exceeded the performance of individuals working in non-interactive groups, EBS, however, is the exception.

Valacich et al (1994) found that for *larger* brainstorming groups comprising nine, 12 or 18 members, EBS produced more ideas than non-interacting groups of the same sizes. As a result of this study it is unclear what the ideal group size should be and this will be discussed later. These finding do show that the group interaction can improve performance beyond that of non-interacting groups when measured by the number of unique ideas generated. The purpose of brainstorming, however, is not only to generate more ideas but also to produce more good ideas. Therefore, in order to determine if the group interaction is beneficial, the quality of ideas must also be considered. This issue of quality is discussed in the next section.

Before moving on, it is important to note that thus far, the aforementioned brainstorming procedures have modified the original brainstorming process. Some researchers have considered modifying only part of the process such that a brainstorming group interacts for part of the session and work independently for the remainder of the session (Leggett, et al., 1996, Paulus, et al., 1995). For the purpose of this thesis, these procedures are referred to as hybrid brainstorming. It is unknown how performance with these hybrid procedures compares to strictly non-interactive brainstorming as no studies have as yet made this comparison. The formal study compared hybrid brainstorming with non-interactive brainstorming. A more detailed discussion concerning hybrid brainstorming procedures is resumed later.

Assessments of the Quality of Brainstorming Performance

Osborn's intended purpose of brainstorming was not only to produce more ideas but also more good ideas. Although previous studies predominantly found that groups (interactive groups) did not exceed the performance of individuals (non-interactive groups) when measuring number of ideas, research that examined quality, has had mixed findings. These findings are difficult to interpret.

Defining Quality

Unlike the assessment of quantity, assessing quality is not straightforward as there is no universally shared definition of quality. The diversity in definitions of quality is reflected in the literature. Comparing performance across studies is difficult because quality is not always clearly defined and different measures are used. For example Valacich, Dennis and Connolly (1994) used *importance* for their measure of quality while Dennis and Valacich (1994) used *magnitude of impact.* Still others have used *appropriateness* (Johnson & Raab, 2003), *originality,* (Diehl & Stroebe, 1987; Barki & Pinsonneault 2001), and *feasibility* (Diehl & Stroebe, 1987; Barki & Pinsonneault, 2001; Kramer, Kuo & Dailey, 1997) to name a few. Presently, it is unknown if these different measures for quality yield different results. The formal study used two different techniques for determining quality. The first rates the quality of an idea on a 100-point scale along characteristics that define creative and successful solutions: novel and useful (Gilhooly, 1982). The second uses creativity as a measure for quality which is discussed in more detail next.

Creativity as a Measure for Quality. Unlike previous studies, this thesis uses creativity as

a suitable measure for quality for various reasons. As has been noted, successful problem solvers were found to produce creative solutions (Wallas, 1926). Because this thesis is interested in capturing the potential success of an idea as an indicator of quality, it is reasonable to use creativity as a measure for quality. Furthermore, in brainstorming research, as well as in the present study, the ideas being evaluated have been generated during a short period of time and therefore more closely resemble preliminary ideas than final solutions that would be developed over longer periods of time. The quality of a preliminary idea may not reflect its potential quality.

Because creativity has been linked with problem solving, a measure of group creativity can therefore be used as an indicator of the group's potential to produce a final "good" solution instead of measuring the quality of the groups' initial ideas. Focusing primarily on the quality of an idea or the mean quality of a group of ideas discounts and obscures the importance of other ideas and the relationship among ideas. That is, ideas that are not considered "good" may nevertheless contribute to the production of "good" ideas. By using measures of creativity, various characteristics of the ideas are considered such as the number of idea categories, the number of combinations / elaborations, and the number of original ideas (ideas repeated no more than 5%), which do not underestimate the ideas' potential or their significance in relation to each other. Rather, creativity provides a measure of the group's potential.

Additionally, Guilford's (1967) components of creativity only require evaluators to count the number of idea categories, the number of combinations / elaborations, and the number of original ideas. Quantifying these aspects of creativity makes it a more objective measure of quality than previous ones, which have necessitated judgement ratings on scales. Presumably, these ratings are influenced by the expertise of the rater in the area of the chosen problem. In some instances, raters have been participants (e.g., Kramer, Duo & Dailey, 1997) while other have been external experts (e.g., Johnson & Raab, 2003; Barki & Pinsonneault, 2001). Evaluating Guilford's components of creativity, however, should be less influenced by expertise, as they require counting rather than a rating judgment. For these reasons, the present study also used creativity as a means to assess quality. Finally, in assessing both the creativity of groups and the "novelty and usefulness" of the generated ideas it can be determined to what extent creativity leads to "better" ideas.

Analyzing Quality

Total Quality Scores. Not only have studies varied in their measures of quality but also in their analysis of quality. The majority of studies have used total quality scores; that is, the sum of each unique idea's quality score. While this may be comparable to the quantitative equivalent, total unique ideas, it is problematic in that total quality scores invariably increase as more unique ideas are generated thereby rendering the relationship between quantity and quality inextricably linked. Therefore, groups who generate more ideas should have higher total quality scores than groups who generate fewer ideas. For example, Valacich, et al., (1994) compared their EBS groups to non-interacting groups and they found that the largest EBS group produced the most unique ideas and the highest total quality scores. Dennis and Valacich (1994) also found that EBS groups yielded the most unique ideas and the highest total quality scores compared to non-interacting groups. As a result of using total quality scores, the differences found among groups in quality is artificial and can be attributed primarily to the number of ideas. Assessing the mean quality scores, (i.e. total quality scores divided by unique number of ideas) would eliminate this confound.

Mean Quality Scores. When Valacich, Dennis and Connolly (1994), used the mean quality scores they found that quality actually decreased with increases in group size. This finding is in sharp contrast to the one garnered through the use of total quality scores, which had shown that the largest group with the most number of unique ideas was actually superior. Similarly, differences that Barki and Pinsonneault (2001) had detected in total quality scores among non-interacting groups, EBS groups and interacting brainstorming groups disappeared when mean quality scores were examined. Although using mean quality scores is more informative than using total quality scores it obscures which conditions produced the most good ideas, which is the crux of brainstorming: to produce more good ideas. The formal study not only used mean quality and creativity scores but it also examined which condition produced the most ideas that received a high quality score

The Relationship Between Number of Ideas and Quality of Ideas. Diehl and troebe (1987) did not find any differences between non-interacting and interacting brainstorming groups for mean quality scores; however, when they examine total "good" ideas as defined by the highest or second highest possible quality score, they found that non-interacting groups produced more good ideas than interacting brainstorming groups. Currently it is not known how performance for generating good ideas compares for other interacting brainstorming procedures to non-interacting brainstorming. Furthermore, it is unknown if generating more ideas does produce more good. Diehl and Stroebe (1987) did note that the "number of good ideas tended to parallel those for number of ideas" (p. 501) but this observation was not empirically verified. Johnson and Raab (2003) examined the distribution of quality of ideas for a single brainstormer and noted that the quality of an idea deteriorates with each successive idea generated. Therefore, the best ideas were produced first. This finding indicates that the number of good ideas would not have paralleled the number of ideas for a single brainstormer. Therefore, it may not be beneficial for a single brainstormer to generate many ideas unless their ideas are shared with other brainstormers, which could provide them with inspiration to generate more good ideas. This hybrid brainstorming, which involves brainstorming non-interactively followed by brainstorming interactively, could prove the most advantageous, as individuals could first generate their best ideas and then share them with others in order to build on, improve and inspire more ideas. Professionals tend to use interacting brainstorming after a non-interacting brainstorming component in which ideas are generated separately and individually (Paulus et al 2001). Hybrid brainstorming procedures are discussed next.

Hybrid Brainstorming Procedures

Hybrid brainstorming procedures, which combine interactive and non-interactive brainstorming into one session, provide an alternative method to coping with process losses. Hybrid procedures completely eliminate the group interaction, and hence process losses, for part of the session and preserve the group interaction, unmodified, for the other part of the session. Thus, this procedure can be conducted in one of two ways: 1) non-interactive brainstorming (i.e., individually) for the first phase (phase I) followed by interactive brainstorming (i.e., in group) for the second phase (phase G) or 2) vice versa, interactive brainstorming (i.e., in group) for the first phase (phase G) followed by non-interactive brainstorming (i.e., individually) for the second phase (phase I). These two procedures will be referred to as I-G and G-I respectively.

Leggett, et al., (1996) and Paulus, et al., (1995) are among some of the very few researchers who have examined the impact of combining interactive and non-interactive phases into one brainstorming session although this technique is commonly used among practitioners (Paulus, Larey & Dzindolet, 2001). Their findings have been mixed.

In one study individual brainstorming followed by group brainstorming (I-G) yielded similar overall results to a group-first and individual-last sequence (G-I) (Paulus, et al., 1995). However, another study found that the group-first individual-last sequence (G-I) enhanced productivity compared with the individual-first and group-last sequence (I-G) (Leggett, et al., 1996). A possible explanation for this discrepancy is that during the I-G sequence, participants tend to share ideas during the second session rather than generate more new ideas. This issue is addressed later in the preliminary studies.

In addition to these contrary findings, much remains unknown. For example, performance of hybrid brainstorming groups has not been compared with non-interacting groups. Also, only the number of ideas has been used as a measure of brainstorming performance. One purpose of the formal study was therefore to compare the hybrid groups with the non-interacting group (I-I) and to use Guilford's components of creativity to measure performance. Thus far, no study has made this comparison and few have examined hybrid brainstorming and none have employed Guilford's component of creativity. Consequently, there is little to no empirical research to guide any predictions of performance. In 1988, Brown, et al., proposed using cognitive psychology's concept of a semantic network to provide a framework for representing the cognitive factors which underlie brainstorming. By employing this framework, predictions regarding the performance of the hybrid and non-interacting brainstorming groups can be made. This framework is discussed next.

A Cognitive Model for Brainstorming

In 1983 Anderson proposed the spreading activation theory of memory. This theory proposed that knowledge is represented in an interconnected semantic network and that retrieval of information is performed by spreading activation throughout the network. Brown, et al., (1988) later proposed using this same model to represent the cognitive factors which underlie brainstorming.

A semantic network can represent an individual's knowledge where nodes represent concepts and connections indicate an association. Each individual has a different semantic network representing his / her own knowledge and as such the presence of specific concepts will vary as will the strength of association among them. The stronger the association between concepts is, the stronger the connection. Arguably, strongly related concepts share membership to the same category and weakly related concepts do not share membership to the same category (Reder & Anderson, 1980).

A concept will activate closely related concepts (members of the same category) quickly and first (Brown, et al., 1988). Distantly related concepts (i.e. concepts remotely related to the activated category) with the weakest connections are slowly activated and later. Concepts that are connected to any activated concept may also become activated and continue to activate other concepts. Thus remotely related concepts will activate a new category and the corresponding concepts associated with that category. Over time as more concepts become activated, more categories should also be activated. Later activated concepts may only be remotely related to the original concept. In brainstorming, the original concept is the problem.

Once concepts are activated they are brought into working memory (Anderson, 1983). In the case of brainstorming, these concepts are expressed as ideas. Through this process of spreading activation, numerous concepts and by extension categories can be activated. An individual will begin to run out of ideas when the majority of related concepts have been activated. It is possible to externally activate new and unexplored concepts in an individual's semantic network thereby increasing the number of ideas generated in a brainstorming session. This notion will be discussed in detail later.

As semantic networks differ across individuals, each individual's collection of activated concepts will vary. In instances where individuals' share similar knowledge there should be more overlap of ideas than for individuals' who share dissimilar knowledge. Therefore, combining ideas generated across non-interacting individuals will result in some repeated ideas and some unique ideas. The extent to which ideas are repeated is dependent upon the composition of the non-interacting group's combined knowledge.

Exposing an individual to other group members' ideas can activate new categories of concepts in that individual's semantic network and build associations between concepts that would otherwise not have occurred. As a result of more concept activation in the semantic network, the individual will generate more ideas, combinations or elaborations of established ideas and potentially more original ideas than if they had not been exposed to other members' ideas. The benefit of exposure to others' ideas has been an argument for group interaction. As discussed earlier, group interaction has been associated with various process losses which reduce idea generation. Various studies have attempted to modify the interaction such that process losses are minimized. Few studies have examined the impact of modifying when interactions happen (Leggett, et al., 1996, Paulus, et al., 1995).

Leggett, et al., (1996) and Paulus, et al., (1995) compared brainstorming groups where individuals interacted for the first half (G-I) or last half of a brainstorming session

(I-G). The advantage of controlling when interaction occurs is that individuals are given the opportunity to generate ideas without the impact of process losses. Empirically it is unknown if interaction is most beneficial after individuals have brainstormed non-interactively (I-G) or if interaction is most beneficial before individuals brainstorm non-interactively (G-I); however, theoretical predictions can be made based on the cognitive model.

Predictions from the Cognitive Model and Previous Research

I-G versus I-I

Theoretically, ideas that are generated during the first phase of brainstorming provide an initial foundation for ideas that can be combined or inspire new ideas during the second phase of brainstorming. Based on previous findings, more ideas should be generated when groups brainstorm non-interactively than when they brainstorm interactively. Therefore, I-G and I-I should generate more ideas in the first session than G-I. Presumably, for the I-G and I-I condition these individuals will begin to run out of ideas at the end of the first session (i.e., they have nearly maximized internally generated spreading activation of the semantic hierarchy). At this point, exposure to others' ideas would activate new areas, or categories of concepts, in their semantic network that correspond with the areas that have been activated in others' semantic networks. Unique associations or concepts in an individual's semantic network would result in more idea generation. As a result, each group should produce more ideas in each category, including elaborations / combinations and more original ideas. Thus I-G should out-perform I-I as the non-interactive group will run out of ideas sooner without the external stimulation. Therefore, I-G should produce more ideas, idea categories, combinations /

elaborations and original ideas; as these are the components of creativity I-G should also outperform I-I for creativity. The purpose of brainstorming is ultimately to produce good ideas. As discussed, creativity is associated with good solutions and ideas; thus, I-G should also produce the best quality ideas. These predictions are outlined in Table 1.

Table 1.

Comparison brainstorming performance between I-G and I-I

Number of Ideas	I-G > I-I
Number of Categories	I-G > I-I
Number of Elaboration / Combinations	I-G > I-I
Number of Original Ideas	I-G > I-I
Creativity	I-G > I-I
Quality	I-G > I-I

G-I versus I-I

For groups who interact at the beginning of brainstorming and not at the end (G-I), these groups will produce fewer ideas compared to the non-interactive group at the end of Session 1. At the beginning of Session 2 the non-interactive group I-I will be running out of ideas as previously mentioned, but G-I will have the benefit of exposure to others' ideas from Session 1. Theoretically, exposure to others' ideas will increase the number of activated categories and hence the number of ideas and original ideas in addition to the number of opportunities to elaborate on and combine ideas. As a result, G-I will benefit from the interaction and overall will outperform the non-interactive groups I-I (See Table 2).

Table 2.

Comparison of brainstorming performance between G-I and I-I

Number of Ideas	G-I > I-I
Number of Categories	G-I > I-I
Number of Elaboration / Combinations	G-I > I-I
Number of Original Ideas	G-I > I-I
Creativity	G-I > I-I
Quality	G-I > I-I

G-I versus I-G

As a result of process losses caused by interaction, G-I will have generated fewer ideas than I-G. Therefore, from the larger foundation of ideas, I-G will have more opportunities for activation which can inspire new ideas, elaborations or combinations. During Session 2, when I-G individuals are interacting they may encounter greater process losses compared to the interactive session in G-I. During I-G's interactive session group members have a large overhead of ideas to review; unlike G-I individuals who do not have this additional task to contend with. As a result, I-G may have more potential opportunity to generate ideas but fewer resources available to do so compared to G-I.

G-I groups are exposed to fewer ideas from other group members compared to I-G groups and thus may have fewer categories activated in their semantic network which could result in fewer ideas, original ideas, and idea elaboration / combinations. These groups, however, have the benefit of a non-interactive brainstorming session (free of process losses) following interaction whereas I-G groups do not. As discussed, due to process losses encountered during interaction, I-G groups will not be able to generate all theoretically possible ideas. This is also true for G-I group during their interactive session as well, (Session 1) however, these groups have the opportunity to continue generating ideas during non-interactive session. Therefore, exposure to others' ideas may increase the potential to generate more idea categories, ideas, original ideas, elaborations and combinations; however, the opportunity to generate these potential ideas is also necessary. Although I-G groups arguably may have more potential as a result of greater exposure this group lacks the opportunity to express that potential compared to G-I groups. Consequently, G-I should outperform I-G as well as I-I (See Table 3).

Table 3.

Comparison of brainstorming performance among G-I, I-G and I-I

Number of Ideas	G-I > I-G > I-I
Number of Categories	G-I > I-G > I-I
Number of Elaboration / Combinations	G-I > I-G > I-I
Number of Original Ideas	G-I > I-G > I-I
Creativity	G-I > I-G > I-I
Quality	G-I > I-G > I-I

Duration of Brainstorming Sessions

Although there is no standard, a brainstorming session may range from 15 minutes to 30 minutes (e.g., Hymes & Olson, 1992; Cooper, Gallupe, Pollard & Cadsby, 1998; Barki & Pinsonneault, 2001; Scudder, Herschel & Crossland, 1994; Valacich, Dennis & Connolly, 1994; Dennis & Valacich, 1994; Price, 1985). However, Leggett, et al., (1996) found two 25-minute sessions resulted in higher productivity than two 15-minute sessions. As there is no standard length for a brainstorming session, preliminary studies were conducted in order to determine an appropriate length. A qualitative analysis of each session was also conducted on the formal study to determine group productivity over time: the rate at which ideas were generated, when the majority of ideas were produced and if idea generation ceased before the full time elapsed.

Group Size

The issue of group size has been studied extensively (e.g., Valacich, Dennis & Connolly, 1994; Dennis & Valacich, 1994). Valacich et al., (1994) noted that group size affects number of ideas generated, total quality scores and mean quality scores differently for EBS and non-interacting groups. These results may apply mainly to EBS and nominal brainstorming procedures; the brainstorming process the present study utilizes is rather unstudied and consequently, it is unknown what the ideal group size is. There is some evidence that smaller groups may be more effective at generating "better" ideas. Heller and Hollabaugh (1992) found that groups of three and four generated better plans for solving problems and produced fewer mistakes with conceptual problems than larger groups. A more detailed analysis of individual member participation revealed that the frequency of participation was similar among members in 3-person groups. Each member of the group of three made 38%, 36% and 26% of the total number of contributions to the solution. The additional member in the group of four, however, only contributed an average of 8% of the total number of contributions to the solution.

Contributions among the other members of the four-person group were similar to that of a three-person group. As a result of this finding, the formal study used small groups of three.

Brainstorming Tasks

The tasks typically used in brainstorming research are generic and lack complexity thereby requiring very little expertise. Examples include asking subjects to provide solutions to problems such as *how to reduce the spread of AIDS* or *how to reduce violent crimes (*Barki & Pinsonneault, 2001), or *how to improve the relationship between the German population and guest workers* (Diehl & Stroebe, 1987). Occasionally, the theme of the task reflects a domain with which participants are familiar but that still requires very little expertise, for example, asking business students to identify all individuals, groups and organizations that would be affected by a new policy requiring them to own or have access to a personal computer (Valacich, Dennis & Connolly, 1994), or asking them *how* they would be affected by such a policy (Dennis & Valacich, 1994). Furthermore, the tasks used to study brainstorming do not reflect real-world problem solving in Human Computer Interaction (HCI). Examples of problems encountered in HCI include asking participants to define a classification system for images for amateur photographers (Grinter, 2005) or designing a collaborative learning experience by scoping out the design space for Computer Supported Cooperative Work in museums and galleries and investigating how people collaboratively encounter and explore technological exhibits in museums and galleries (Hindmarsh, Heath, Lehn & Cleverly, 2005).

When brainstorming is studied in HCI, it often investigates the supportive role technology can play to facilitate brainstorming, typically for non-collocated brainstormers. For example, Hymes and Olson (1992) examined the impact of using a group editor in brainstorming; however, their brainstorming task was largely unrelated to HCI. Their participants were asked to generate a list of objects in a modern, middle class house that a visitor from a low-technology environment, such as a Siberian Eskimo, would find bewildering. Hence, very little work has been done examining brainstorming within the context of an HCI task aiming to identify, for example, features a given application should provide.

Brainstorming tasks in the HCI area are typically complex, such as designing interactive experiences. These differ from the much simpler tasks that are typically used to study brainstorming such as listing objects in a home. Therefore, one purpose of the first preliminary study was to determine the suitable complexity of an HCI task to study the idea-generation process of brainstorming. A task relevant to the design of an interactive cybercartographic atlas was chosen.

It is unclear how brainstorming is conducted most effectively when the objective is to solve an HCI-related problem. Therefore, a second objective of the first preliminary study was to test the appropriateness of the brainstorming procedure planned for this thesis. The I-G (Individual – Group) and G-I (Group – Individual) conditions were explored here to address procedural issues such as the duration of a brainstorming session and the time required to change from G to I, and I to G.

PRELIMINARY STUDY 1

Method

Design

Two groups of four participants completed the brainstorming task in a session that was intended to last one hour. The session, in fact lasted, 2 hours; an explanation for the discrepancy is presented in the discussion. One group brainstormed individually (I) for the first half of the session and as a group (G) for the second half. The other group brainstormed as a group (G) for the first half of the session and then individually (I) for the second half. The total number of unique ideas generated, that is, not including repetitions, was used to compare brainstorming performance between the two conditions. The group condition was led by an experienced facilitator who was familiar with the rules of brainstorming and was instructed to enforce these rules. She was also well acquainted with the brainstorming task. However, the facilitator was not informed of any expected differences between the two brainstorming conditions, I-G and G-I.

Participants

In response to an email sent to graduate students involved in a multidisciplinary academic project to produce interactive cybercartographic atlases, eight students representing disciplines including psychology, geography, and computer science, volunteered to participate and were assigned randomly to a group of four. They were not paid for their participation.

Materials

Each participant was provided with pen and paper to record their ideas in the I (individual) condition. In the G (group) condition, the facilitator recorded ideas with a marker on a flip chart that was visible to the participants.

Procedure

On arrival participants were greeted by the brainstorming facilitator. Participants filled out informed consent forms (please see Appendix A).

Once all four participants had arrived, the facilitator verbally informed them that they would be brainstorming individually and as a group on the same topic. The participants were also told the order in which they would be brainstorming i.e., G-I or I-G. Next, the facilitator provided written and verbal instructions on the brainstorming task. It required participants to generate a list of features that a multimodal multimedia atlas of Antarctica should provide to users who plan on visiting Antarctica and who wish to learn about it before they leave, and give presentations regarding what they learned once they return from their visit. The task is presented in Appendix B. Participants were also provided with a written and verbal overview of the information users would typically seek before going to- and after visiting Antarctica. This included a list of nine topics that users may research such as Flora and Fauna. Each topic included four types of activities that users may pursue, exploring general information, learning specific information, speculating on the unknown effects of certain factors, and learning information that is relevant for future personal experiences. An example of an activity is "specialization" where a user selects a specific example of Flora and Fauna, such as the Arctic Tern, to research (see Appendix C for details).

Finally, the facilitator provided written and verbal instructions pertaining to the following rules of brainstorming: 1) criticism is not allowed, 2) freewheeling is welcomed, 3) quantity is wanted, and 4) combinations and improvements on ideas are sought. Participants were then either seated alone in small rooms (individual condition, I) or led into a larger room (group condition, G). Four observers, including the three raters and the experimenter, took notes and monitored the group condition from a control room through a one-way mirror but did not comment or interact with the participants.

For the I-G condition, participants were seated in separate rooms where they brainstormed individually for 10 minutes. Following a brief two-minute break, the members of the group were seated together at a table where they shared their ideas verbally. The facilitator recorded ideas that were shared and new ones that were produced on a large flip chart at the end of the table. The facilitator also ensured that the rules of brainstorming were followed and that all members of the group had the opportunity to share ideas. Once all ideas had been shared and discussed the participants were thanked for their time and debriefed.

For the G-I condition, participants were seated around a table generating ideas verbally for 10 minutes. As in the other condition, the facilitator ensured that the rules of brainstorming were followed and that all members participated. Also, the facilitator recorded all ideas on the flip chart. After a two minute break, participants were seated in separate rooms where they resumed idea generation individually for 10 minutes. Following the individual idea generation session, participants came together to share their ideas in the same way as the other group. The facilitator was also present at this point, recording ideas as before and enforcing the rules of brainstorming. Once the group had finished sharing ideas they were thanked for their time and debriefed.

Scoring

Ideas were combined across the two phases (G-I; I-G) to produce a single list of ideas for each group. Three independent raters who had not participated in, but who observed, the brainstorming session counted the number of ideas produced during these brainstorming sessions. The raters first worked independently to count the ideas and then compared notes and discussed at length their results. The result of this process is discussed next.

Results and Discussion

All three raters agreed that counting the ideas was not as straightforward a task as had been assumed. The challenge arose primarily from the variability in generality/specificity of ideas. A general idea is broad or represents a theme but does not provide a concrete example of how this theme can or should be realized. An example of a general idea was "provide collaborative technologies for group work online". Conversely, a specific idea is a narrow representation of a broad idea. For example, "provide a chat room" is one specific potential solution to the more general idea "enable online group work". The former may thus be regarded as a sub-component of the latter. The problem was that ideas such as that example were similar but did not overlap perfectly. This made it difficult to determine the extent to which an idea was unique or redundant.

Another problem encountered was variations in idea complexity. A complex idea was composed of multiple smaller ideas whereas a simple idea had only one component.

An example of a simple idea is “provide links to external websites”. In contrast, an example of a complex idea was “provide an online travel journal, which allows for text, video, photos, audio recordings, and customized maps”. These variations in idea complexity complicated counting in that it was unclear what represented one idea.

After a lengthy discussion the raters decided to categorize the ideas independently in order to simplify their task. They met to discuss their results and realized that categorization proved as challenging as counting ideas. As many ideas overlapped partially but not perfectly, it was difficult to devise mutually exclusive categories that could separate ideas perfectly into groups. Rather, an idea could often fit into two categories. It was particularly difficult to determine category membership of complex ideas that could not easily be subdivided into smaller ideas. For example, the “travel journal” idea could belong to the categories maps, external contributions, and presentations, among other possibilities. Consequently, the raters were unable to accurately determine the number of unique ideas that had been generated.

Difficulties counting ideas have not previously been reported in the brainstorming literature. Past brainstorming studies, however, have used tasks, which are narrowly focused e.g., identify all individuals, groups and organizations that would be affected by a new policy requiring all business students to own or have access to a personal computer (Valacich, Dennis & Connolly, 1994; Dennis & Valacich, 1994). One way to attempt to simplify the counting of ideas could be to give participants a narrower task than the one used here. A review of the literature revealed only one previous study that has examined the impact of the complexity of the brainstorming task on brainstorming performance (Dennis, Valacich, Connolly & Wynne, 1996). Dennis, et al., (1996) compared intact tasks with decomposed tasks. An intact task is composed of various subcomponents and a decomposed task is one that cannot be further subdivided. For example, Dennis, et al., (1996) asked participants to identify the important outputs, inputs and data elements of a proposed computer system for a video rental company, as an intact task. The three subcomponents of this task or the three decomposed tasks are the identification of the outputs OR the inputs OR the data elements for the proposed computer system for the video rental company. They found that participants who brainstormed on decomposed tasks generated 60% more ideas and more good ideas than participants who brainstormed on intact tasks. Although they did not report any differences in the number of ideas between the two-task conditions, their intact task was less complex than the one used in this preliminary study. That is, Dennis and colleagues' (1996) intact task could be subdivided into three parts whereas the present study's task could be subdivided much further (e.g., features by type of media, features by type of mode, features for giving presentations, features for learning, etc). Given this evidence suggesting that narrower brainstorming tasks result in better performance, the second preliminary study examined a narrower task to test the prediction that it would also simplify the task of counting ideas.

The breadth and complexity of the task also proved problematic because the duration of the brainstorming session by far exceeded the time initially allotted. The brainstorming session was designed to last approximately one hour but the brainstorming groups could not complete their task in that time. Participants brainstormed either intact tasks, where all parts of the task are presented simultaneously, or decomposed tasks, where the subcategories of the intact task are presented. Based on Dennis, et al.,'s (1996) results for brainstorming performance on decomposed tasks, it is assumed that an hour-long brainstorming session should be sufficient for a narrower brainstorming task, (a task that is composed of few or no other subtasks). This was tested in the second preliminary study.

As HCI tasks are not studied in the brainstorming literature, it is unclear what would constitute a narrow HCI task. Valacich, Dennis and Connolly's (1994), and Dennis and Valacich's (1994) brainstorming task was reframed in a context relevant to HCI. It was anticipated that the narrower task would resolve the complexities surrounding counting ideas.

Finally, since no identifiable problems were encountered with the G-I / I-G procedure it was not modified for the second preliminary study. It was observed, however, that the role of the facilitator was superfluous, as she was not required to provide assistance or remind participants of the brainstorming rules. As a result, no facilitator was used during the second preliminary study.

PRELIMINARY STUDY 2

A second preliminary study was conducted with a different, much simpler brainstorming task. In the first study the HCI brainstorming task proved to be more complex than those typically used in brainstorming research. The task was composed of many subtasks according to Dennis, et al.'s definition (1996), which resulted in ideas varying in complexity, often comprising multiple ideas. In order to overcome the problem of counting ideas and to adhere to a more appropriate topic for brainstorming, the formal study employed a simpler task to verify that it would reduce idea complexity and thus facilitate the task of counting unique ideas.

The task originally used by Valacich, Dennis and Connolly (1994), and Dennis and Valacich (1994) in which participants identified individuals, groups and organizations that would be affected by a new policy requiring business students to own/have access to a personal computer was reframed here to create an HCI-relevant context. Reframed, the task asked participants to "identify ways in which collaboration across a multi-disciplinary project could be promoted and supported". This task was considered suitably narrow, as it was difficult to see how it could be further decomposed into multiple smaller tasks. Additionally, the selection of this more focused task was also considered more suitable to an hour long brainstorming session unlike the task used in the first preliminary study, which had required twice the time initially allotted.

Method

Design

Two groups of five participants completed the brainstorming task in one session lasting approximately one hour. As before, one group brainstormed individually (I) for the first half of the session and brainstormed as a group (G) for the second half, and vice versa for the other group. The total number of unique ideas generated was used to compare brainstorming performance between the two conditions.

Participants

Members of a sub-group that was responsible for promoting and supporting collaboration in the same project as employed in the first preliminary study participated in this brainstorming session. The two groups included eight graduate students and two professors each representing different disciplines, which included psychology, geography, computer science and cognitive science. Participants were not paid for their time.

Procedure

Upon arrival participants were verbally instructed on the rules of brainstorming and their brainstorming task. The same brainstorming procedure was used for the brainstorming conditions (I-G and G-I) as in the first preliminary study. As previously noted, the role of the facilitator during the first preliminary study was superfluous as participants did not require assistance or to be reminded of the brainstorming rules. Therefore, no facilitator was employed during the second preliminary study. Instead, a participant from each group recorded the group's ideas on a blackboard that was visible to the entire group. Also, for the I condition, participants recorded their ideas on paper as in the previous study; however, they did not work in separate rooms but did this in the same area due to unavailability of appropriate physical space. This deviation from the first preliminary study was not expected to affect the results.

Results

For condition G-I, the sum of participants' ideas across both sessions was 48. Once repetitions were removed, 45 unique ideas remained which were grouped into eight categories. Of the 45 unique ideas, 13 were elaborations. For the I-G condition, 36 ideas were generated, 33 of which were unique ideas that were grouped into nine categories. Of the 33 unique ideas, 11 were elaborations. To calculate the number of original ideas, only ideas that are repeated less than 5% over the sample are included. In this instance, the sample size is small and any idea that would be repeated less than 4 times should be counted. As this study only used two groups, repetitions were minimal and thus all ideas

(G-I = 45, I-G = 33) would be considered original. The high number of original ideas can be primarily attributed to the few groups being tested and the reduced opportunity for repetitions. No statistical analyses were conducted as the author was primarily interested in determining if using a narrower task would facilitate counting ideas and evaluating ideas.

Discussion

The narrower brainstorming task did facilitate counting ideas. Indeed the ideas produced in this study tended not to overlap to the same degree as they had in the previous study, which made it considerably easier to identify unique ideas. When ideas did overlap they turned out to be instances of other ideas. For example, a broad idea was to have "social activities" and another idea, which is a subset of this one, was a "film night". Still, some ideas were elaborations or combinations of other ideas. For example, the idea to "use the collaboration process as research data" was elaborated on to "have the project recognized as a case study to be developed by a third outside party such as the Harvard Business School". Once the number of unique ideas had been counted, ideas were easily grouped into categories and elaborations on ideas and combinations of ideas could be counted. Thus, narrowing the task greatly facilitated identifying and counting unique ideas in addition to categorizing ideas and counting the number of elaborations / combinations thereby fulfilling the purpose of this preliminary study.

Additionally, limiting the scope of the brainstorming task successfully reduced the length of the brainstorming session to one hour, which conforms to traditional brainstorming practices. As a result of this finding, a similarly narrow task was used in the main study.

While practitioners often employ individual brainstorming before group brainstorming to enhance performance, this study found that in fact group brainstorming before individual brainstorming was more effective than the reverse. A notable difference, however, was observed between the two conditions thereby making the difference impossible to solely attribute to the order of brainstorming type. In the G-I condition, participants generated ideas in both the group and the individual components. During the I-G condition, however, participants generated ideas only during the individual component and simply shared ideas during the group component without elaborating on ideas, combining ideas, or generating new ideas. Rather, the group component in the I-G condition did not in any way add to ideas that had been produced in the individual component. This may explain the larger number of ideas emerging from the G-I group. As such, the I-G condition spends only half the brainstorming session actually generating ideas. A similar finding was noted by (A. Parush, personal communication, March 4, 2005) who conducted a brainstorming session with the I-G and G-I conditions.

In an attempt to resolve this discrepancy and promote greater idea generation over idea sharing in the formal study, the brainstorming instructions were modified to emphasize idea generating and deemphasize idea sharing. The experimenter also monitored brainstorming groups to insure that the instructions were being followed. In instances where groups were primarily sharing ideas they were interrupted by the experimenter and reminded to try and generate new ideas rather than discuss old ones. Additionally, an idea sharing technique used by Constantine (2004) in a workshop brainstorming session was used in the formal study. This technique requires participants to record each idea on a cue card and place all cue cards in the centre of the table as they share their ideas. When more than one person has the same idea, all cue cards representing that idea are placed on the table simultaneously. Participants are instructed to record new ideas on cue cards as they come to mind and place the cards in the centre of the table. This procedure would differ slightly for the I-G condition. At the beginning of the interactive session (G), participants would place all their idea cards from the previous non-interactive session in the centre of the table for all to see. Brainstorming would then continue as previously described. This technique allows groups to share air-time more efficiently, and it promotes discussion as participants are instructed to explicitly indicate when they have produced the same idea or a similar idea. In contrast, when groups share ideas verbally as was done in the first preliminary studies, participants hesitated to interrupt each other and simply did not state redundant or similar ideas. By promoting discussion this may encourage generating new ideas or elaborating on others ideas and should thereby render the two brainstorming conditions, I-G and G-I more similar in terms of time spent working towards generating ideas. The G-I condition may prove advantageous as participants have longer to reflect on, derive inspiration from and elaborate on ideas generated during the group condition. This would therefore result in more elaborations, more ideas in each idea category, and thus more ideas. By contrast, participants in the I-G condition are only exposed to the ideas of others for the second half of the brainstorming session and thus they do not have the same amount of time to reflect on, derive inspiration from or elaborate on these ideas, thereby resulting in fewer ideas than in the G-I condition.

Alternatively, the mere exposure to others' ideas initially may inhibit participants from generating different ideas and instead may simply promote elaboration on previous ideas. Stewart and Stasser (1995) noted that in groups there is a tendency to reinforce or respond favourably to ideas that individuals have in common. This reinforcement may lead to a tendency to share common rather than uncommon or unique ideas (Larey & Paulus, 1999). Thus the I-G condition may promote more idea categories with fewer ideas in each category whereas the G-I condition may promote more ideas in fewer idea categories. In fact, this preliminary study did find that the G-I condition did generate more ideas and more elaborations than the I-G condition and that the I-G condition produced more ideas categories than the G-I condition. Although the differences are small and came from a small sample they may become magnified when idea sharing in the interactive component of the G-I condition is reduced. Nevertheless, both number of idea categories and number of ideas are components of creativity. Therefore the two conditions may promote different components of creativity. This will be further investigated in the formal study, where both the number of unique ideas and the creativity of ides generated will be evaluated. As a result of this study, predictions regarding number of original ideas was adjusted to I-G > G-I > I-I.

FORMAL STUDY

In the second preliminary study a narrow brainstorming task was selected, which successfully reduced idea complexity and facilitated the task of counting ideas. It was noted that the two groups differed in the number of ideas they generated. The sample size, however, was small and therefore it could not be determined if this difference was statistically significant. It was observed that participants engaged in different activities during the group (G) session depending on which condition they were assigned to, I-G or G-I. Participants in the G-I condition generated ideas during the interactive session whereas participants in the I-G condition only shared ideas they had generated during the non-interactive (I) session. It was proposed that this discrepancy could account for differences in number of ideas generated. Therefore, in order to minimize this discrepancy in idea generation between the two conditions, participants wrote their ideas on cue-cards, during the formal study, in order to more efficiently share air-time and thus facilitate idea sharing and promoting idea generation as discussed in the previous section. As a result, any differences between the groups can be attributed to the brainstorming condition.

The two preliminary studies used groups of four and five members respectively. As previously noted, there is no standard brainstorming group size. There is evidence that smaller groups generate better ideas. According to Heller and Hollabaugh (1992), groups of three and four generated better ideas for solving problems and produced fewer mistakes with conceptual problems than larger groups. However, upon closer examination, adding a fourth member to a brainstorming group does not increase brainstorming performance beyond that of a 3-member group. Based on these findings, the formal study employed groups of three and conducted an analysis to compare the proportion of contributions from each participant in order to determine if the results accurately reflect equal participation from the three individuals.

It was also noted that there is no standard duration for a brainstorming session. Sessions have ranged from 15 minutes to 30 minutes. The second preliminary study found that two 20-minute sessions provided participants with ample time to complete the narrower brainstorming task. Therefore, the formal study consisted of two 20-minute sessions; however, a qualitative analysis was conducted on each session and across sessions to determine group productivity over time: the rate at which ideas were generated.

Thus far, the preliminary studies have only counted the number of ideas. As previously discussed, the goal of brainstorming is not only to generate more ideas, but also to produce more good ideas. It has been shown that good solutions are the product of creative individuals. Therefore, to compare brainstorming performance across conditions, the number of ideas was counted along with quality ratings and Guilford's (1967) other components of creativity, namely the number of idea categories, the number of elaborations or combinations of ideas and the number of original ideas.

In the brainstorming literature the condition that is here called 'non-interactive' has served as the baseline for performance comparison. Therefore, in addition to the I-G and G-I conditions, the formal study employed an I-I condition as well to which performance was compared. It has been well established that traditional interactive brainstorming groups do not outperform non-interactive ones (Van de Ven & Delbecq, 1971). Therefore, as the researcher is primarily interested in exceeding the performance, of the currently best known brainstorming procedure, 'non-interactive', a G-G condition was not included.

According to Osborn (1957), interactive groups should produce more ideas and better ideas than individuals as groups have more opportunity to combine and elaborate on each others' ideas and can draw inspiration from each others' ideas and their strengths. Thus, groups should generate more ideas and be more creative, thereby generating better ideas as well. The interactive brainstorming group, however, encounters process losses which the non-interactive brainstorming group does not. As such, interactive groups may be unable to realize their potential (Steiner, 1972) preventing them from outperforming non-interactive groups. Therefore, the hybrid brainstorming conditions, G-I and I-G, which balance process losses with the benefits of the group interaction, should outperform the non-interactive condition, I-I, which does not incorporate the proposed benefits of group interaction. Thus the hybrid conditions should be more creative and produce more ideas and higher quality ideas as shown earlier in Table 3 (p. 31). Additionally, as predicted from the cognitive model, interaction should be most beneficial in Session 1 followed by non-interaction in Session 2. The results from Preliminary Study 2 also indicate that hybrid conditions may differ on some components of creativity including the number of ideas. Results from the second preliminary study suggest that group interaction may be more beneficial at the beginning of a brainstorming session than at the end, possibly because G-I participants have more time to reflect on, draw inspiration from, and elaborate on ideas generated during the group condition. The net result is more elaborations, more ideas in each idea category, more original ideas and more ideas overall. Participants in the I-G condition are only exposed to the ideas of others in the second half of the brainstorming session and thus have half the time to reflect on, draw inspiration from and elaborate on these ideas thereby resulting in fewer ideas than in the G-I condition.

Therefore, hypothesis 1 predicts G-I will generate the most ideas followed by I-G, and then I-I. Because non-interacting groups outperform interacting groups as measured by number of ideas, for Session 1 I-I and I-G should outperform G-I for number of ideas.

Hypothesis 1a predicts that I-I and I-G will generate more ideas than G-I for Session 1. For Session 2, performance should decline for I-I as participants begin to run out of ideas without interaction with other group members. Thus hypothesis 1b predicts that G-I will generate the most ideas, followed by I-I then I-G for Session 2.

Contrary to what the cognitive model would predict the mere exposure to others' ideas may inhibit participants from generating very different ideas and instead may simply promote elaboration on previous ideas. Thus, I-G may promote more idea categories with fewer ideas in each category than G-I. Hypothesis 2 predicts that I-G will generate the most idea categories followed by G-I then I-I. Hypothesis 3 predicts G-I will generate more elaborations followed by I-G then I-I. Hypothesis 4 predicts G-I will generate more original ideas followed by I-G then I-I. Taken together G-I should outperform the other conditions on most measures of creativity. Hypothesis 5 predicts that G-I will be the most creative compared to I-G then I-I. Finally, as creativity should correspond with quality, Hypothesis 6 predicts that the most creative condition will produce the best ideas therefore G-I should produce the best ideas followed by I-G then I-I. These hypotheses are summarized in Table 4 below.

Table 4.

Summary of hypotheses 1-6

Hypotheses	Overall	Session 1	Session 2
Hypothesis 1 Number of Ideas	G-I > I-G > I-I		
Hypothesis 1a Number of Ideas Session 1		(I-G = I-I) > G-I	
Hypothesis 1b Number of Ideas Session 2			G-I > I-I > I-G
Hypothesis 2 Number of Categories	G-I > I-G > I-I		
Hypothesis 3 Number of Elaboration / Combinations	G-I > I-G > I-I		
Hypothesis 4 Number of Original Ideas	I-G > G-I > I-I		
Hypothesis 5 Creativity	G-I > I-G > I-I		
Hypothesis 6 Quality	G-I > I-G > I-I		

Method

Design

Eighteen groups of three participants were randomly assigned to one of the three brainstorming conditions (G-I, I-G or I-I) resulting in six groups per condition. As with the preliminary studies, the session lasted approximately one hour. In each condition, participants generated ideas in two 20-minute sessions. The total number of ideas, total number of original ideas, total number of idea categories, and total number of elaborations or combinations generated were used to compare brainstorming performance in the different conditions. The total number of ideas does not include repetitions; the number of idea categories refers to the number of domains into which ideas can be grouped; the number of elaborations or combinations are the number of ideas that are modifications of other ideas and the number of original ideas is the number of ideas that are reproduced with a frequency no greater than five percent across participants. For a more detailed description of the dependent variables and how they are assessed across session and condition see the section on scoring below. Also, observations were made to determine actual length of time spent generating ideas as well as proportion of contributions from each participant. A summary of the experimental design is provided in Table 5.

Table 5.

Experimental Design of Main Study

Condition	N	Session 1: 20min	Session 2: 20min
I-G	6 groups of 3		
G-I	6 groups of 3		
I-I	6 groups of 3		

Participants

Fifty-four participants were recruited through the Introduction to Psychology course, personal contacts and from posters posted around the university campus. All participants were capable of communicating fluently in English both verbally and written. Each participant received class credit or $10 for his/her time, which did not exceed one hour.

Procedure

On arrival participants were greeted and asked to fill out informed consent forms (Appendix A). They were provided with written instructions on the rules of brainstorming and their brainstorming task (Appendix D and Appendix E), which asked them to "brainstorm ideas about how to facilitate and promote collaboration among a team of multidisciplinary members who work on different but related areas of the same project and who do not all share the same office space or building."

The brainstorming procedure for the conditions (I-G and G-I) was similar to the first preliminary studies with notable exceptions. Participants brainstormed in the same room together throughout the brainstorming session and were asked to record each of their ideas on a separate cue card. Cue cards were coded on the back by the experimenter to indicate the session in which the idea was generated, which participant generated the idea, and its numerical position i.e., if it was the first, second, or third idea generated.

In G-I, where participants began by generating ideas interactively for 20 minutes, they placed their ideas in the centre of the table and stated them aloud, as they generated them. The idea cards remained in the centre of the table for the following 20 minute non-interactive phase of the brainstorming session so that participants continued to have access to the ideas that were generated earlier. In I-G, participants began by brainstorming non-interactively for 20 minutes and recorded their ideas on cue cards but did not share them with the other members of their group. At the beginning of the next 20 minute interactive brainstorming, participants simultaneously placed all of their idea cards in the centre of the table and continued recording new ideas and placing them in the centre of the table while stating them aloud. In I-I, participants generated ideas independently and recorded their ideas on cue-cards for both 20 minute sessions.

The experimenter was present throughout the brainstorming session to observe participants and interrupt the brainstorming session when necessary to remind them to follow the rules of brainstorming or to encourage idea generation. These interruptions, however, were not required as participants in all conditions followed the rules of brainstorming and continued to generate ideas for the duration of the session.

Upon completion of the brainstorming session, participants were debriefed (see Appendix F) and asked for feedback (see Appendix G). Finally, they received $10 for their participation or class credit.

Scoring

Three volunteer coders from the Human Oriented Technology Lab determined the creativity of each group across sessions as defined by Guilford (1967): fluency (number of unique ideas), flexibility (number of idea categories), originality (number of original ideas between participants) and elaboration (combining or modifying ideas). Coders were provided with written instructions, which included definitions and examples to guide them in coding (see Appendix H and Appendix I). This is discussed in greater detail later. A unique code associated with each idea identified from which group, participant, session and order the idea was generated. This code was used to extrapolate the results for each session as determined by the coders. The unit of analysis was the group; thus the ideas from each of the three members of a group were combined into one list that the coders evaluated. The lists of ideas produced by each member of a group were combined to form the group list. The ideas were combined across sessions to yield a single list of ideas per group. Each list was coded independently of the others. The coders were blind as to which condition, I-G, G-I or I-I, each list belonged.

Coding occurred in two phases. In the first phase, coders determined which ideas were duplicates of others for each session-list. The coders were provided with instructions and definitions for determining similarity (see Appendix F). For each list, every idea was written on a separate card with an identifying number on the back. Coders were instructed to group the same ideas and affix them with a paper clip. These groups were transferred to an excel file by the experimenter where each idea was coded with "1" for unique ideas and "0" for repeated ideas. Inter-rater reliability was assessed by comparing the scoring of unique (1) or repeated (0) for all 1309 ideas. Complete agreement was determined to be 70%, 71% and 77% for each rater pair. In instances where all three coders did not agree, the results from the pair that did agree were used. Based on these results, lists of unique ideas were produced. This was done in order to create a single list of unique ideas for coding combinations and elaborations, categories and quality ratings. From this final list, the experimenter determined which ideas were repeated less than 5% across all lists in all conditions to determine if the idea was original.

In the second phase coders were required to group the ideas into categories for each list and then indicate if the idea was a combination of other ideas or an elaboration of another idea. Categorization occurred prior to evaluating combinations and elaborations, as combinations and elaborations should be members of the same category and thus facilitated the coders' task of identifying these ideas once the list has been categorized. Finally, they rated each idea for quality. They were provided with instructions, definitions and examples (see Appendix G). Each idea from every list was presented on a new and separate card.

Coders were asked to group the ideas into categories for each list and record next to the idea a "1" if it is a combination of other ideas or an elaboration of another idea and a "0" if it is not. They affixed the groups with a paper-clip. As the total number of elaborations / combinations per session per group is used in the data analysis, this measure was also used to determine inter-rater reliability. The correlation among the pairs of coders' scores for number of elaborations / combinations per session per group was $r = 0.70$, $r = 0.73$ and $r = 0.77$. The mean number of elaborations / combinations of the three coders for each group session was used for the data analysis. Once each list was grouped, coders rated the extent to which an idea showed promise in being useful and new. Quality was rated on a 100-point scale ranging from "0" (worst quality) to "100" (best quality) on the back of each idea card. Coders rated ideas after repetitions had been eliminated for a total of 1214 ideas. The mean scores were determined per session per group for each coder for the analysis of quality. The mean of these means for each coder was 54%, 57% and 63%. In order to determine the extent to which coders rated ideas similarly, the absolute difference between the mean scores per session per group were determined for each pair of coders. The mean difference for each pair of coders was 6%, 8% and 9%.

Data analysis

The goal of this study is to compare performance among the conditions in order to understand how performance in the hybrid conditions (I-G, G-I) compares to the standard baseline, non-interactive condition (I-I). This comparison can be done within each session and across sessions. Although performance among the conditions could differ from Session 1 to Session 2 thereby resulting in an interaction (Condition x Session), this study is primarily interested in overall performance differences among the conditions across sessions (main effect of Condition). This is reflected in hypotheses 1 – 6 with the exception of hypotheses 1a and 1b. Differences within session, however, are considered secondarily as a means to understand the overall differences among the conditions. Therefore, significant main effects of Condition are considered first. Where significant, interactions are discussed second to help explain differences among the conditions. In instances where differences among the conditions are predicted, planned comparisons are conducted to evaluate the predictions. The main effect of Session is not informative for this study and is not reported.

Differences in creativity are expected among the conditions: G-I should be the most creative followed by I-G then I-I (Hypothesis 5). An overall measure of creativity can be obtained through the combination of number of ideas, number of idea categories, number of elaborations / combinations, number of original ideas. Statistically, this can be achieved with a multivariate analysis on the measures of creativity. To test Hypothesis 5, therefore, a multivariate analysis of variance (MANOVA) with the dependent variables number of ideas, number of idea categories, number of elaborations / combinations and number of original ideas with session as the repeated measure could have been conducted. However, as these dependent variables have not been reported previously in the literature, it is unclear if all these variables are reliable measures of brainstorming performance. To the extent that they are not, they could reduce the power of the MANOVA. Therefore, only the variables number of ideas and number of idea categories were included in the 3 x (2) mixed MANOVA. The number of elaborations / combinations, and number of original ideas were analyzed separately. Note that the multivariate statistic cannot reveal where the differences are across conditions. An examination of the pattern of differences across the measures of creativity revealed where the differences across conditions exist. A significant multivariate main effect for Condition would support the notion that creativity differs across conditions. In order to determine the precise differences, main effect contrasts at the level of each dependent variable were examined separately.

Specific differences were expected among the conditions across the dependent variables.

A significant main effect for Condition with the proper main effect contrasts for the dependent variable, number of ideas, would support hypothesis 1, which predicts that G-I will generate the most ideas followed by I-G then I-I. Not only are differences predicted across sessions but they are also expected for Session 1 and Session 2. As performance across conditions should differ between Session 1 and Session 2, a significant multivariate interaction is expected. A significant simple main effect for condition for the dependent variable number of ideas with the corresponding simple main effect contrasts would support hypothesis 1a, which predicts that I-G and I-I will generate more ideas than G-I in Session 1, and hypothesis 1b, which predicts that G-I will generate the most ideas followed by I-I then I-G for Session 2.

A significant main effect for condition with the corresponding main effect contrasts would provide support for hypothesis 2, which predicts that G-I will generate the most idea categories followed by I-G then I-I across sessions.

To test hypothesis 3, which predicts that G-I will generate the most elaborations / combinations followed by I-G then I-I across sessions, a 3 x (2) mixed ANOVA for the dependent variable number of elaborations / combinations was conducted. A significant main effect for Condition with the proper main effect contrasts would provide support for hypothesis 3.

To test hypothesis 4, which predicts that I-G will generate the most original ideas followed by G-I then I-I across sessions, a 3 x (2) mixed ANOVA for the dependent variable number of original ideas was conducted. A significant main effect for Condition with the proper main effect contrasts would provide support for hypothesis 4.

To test hypothesis 6, which predicts that G-I will generate better ideas followed by I-G then I-I across sessions, an ANOVA for the dependent variable idea quality and an ANOVA for the dependent variable number of good ideas were conducted. A significant main effect for Condition with the proper main effect contrasts would provide support for hypothesis 6.

Additionally, rate of unique idea generation will be examined using the Chow test for Session 1 and 2 and across sessions, to compare the rate of idea generation across conditions. Similarly, to verify and compare individual performance within each group and across conditions, an ANOVA for the dependent variable proportion of participation was conducted for Session 1 and 2 and across sessions.

Results

Results pertaining to creativity are presented in the next section followed by those relating to quality and participation. Inferential statistics are only reported for significant results; the corresponding summary tables are presented in Appendix J through Appendix R.

Creativity

To analyze creativity, a 3 x (2) mixed MANOVA was conducted for number of ideas and number of idea categories. First the multivariate statistics are reported which in part address Hypothesis 5. In instances where a multivariate statistic is significant, the measures, number of ideas and number of idea categories, were examined to determine the locus of the effect.

A 3 x (2) mixed MANOVA for Condition (G-I, I-G, I-I) with repeated measures on Session (1, 2) revealed only a significant interaction, $F(2, 30) = 7.62, p<.001$. The main effect of Condition approached significance, $F(2, 15) = 2.49, p=.066$. To address hypothesis 1 and 2, planned comparisons are presented first for number of ideas and number of idea categories followed by the results for the interaction.

Planned Comparisons

Number of Ideas. Figure 1 shows the mean number of ideas generated in each condition across sessions. G-I appears to have generated the most ideas followed by I-I then I-G.

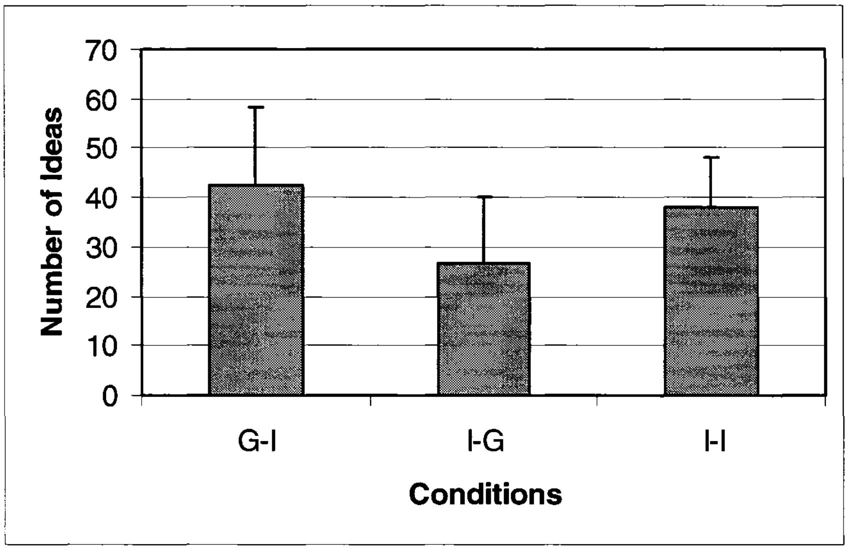

Figure 1. Mean Ideas generated and Standard Deviation for each Condition across Sessions.

G-I did not produce significantly more ideas than I-I; however, G-I did produce more ideas than I-G, $p< .01$. I-I also produced more ideas than I-G, $p<.05$. The difference between G-I and I-G provides support for Hypothesis 1; however, contrary to what Hypothesis 1 predicted, both hybrid groups did not produce more ideas than the non-interactive group. Rather, I-G performed significantly worse than the other conditions.

Therefore, interactivity per se does not appear to enhance idea generation, rather interactivity appears to impair idea generation when it occurs in the latter half of brainstorming.

Number of Idea Categories. Figure 2 shows the mean number of idea categories generated in each condition across sessions. G-I appears to have generated the most idea categories followed by I-I then I-G.

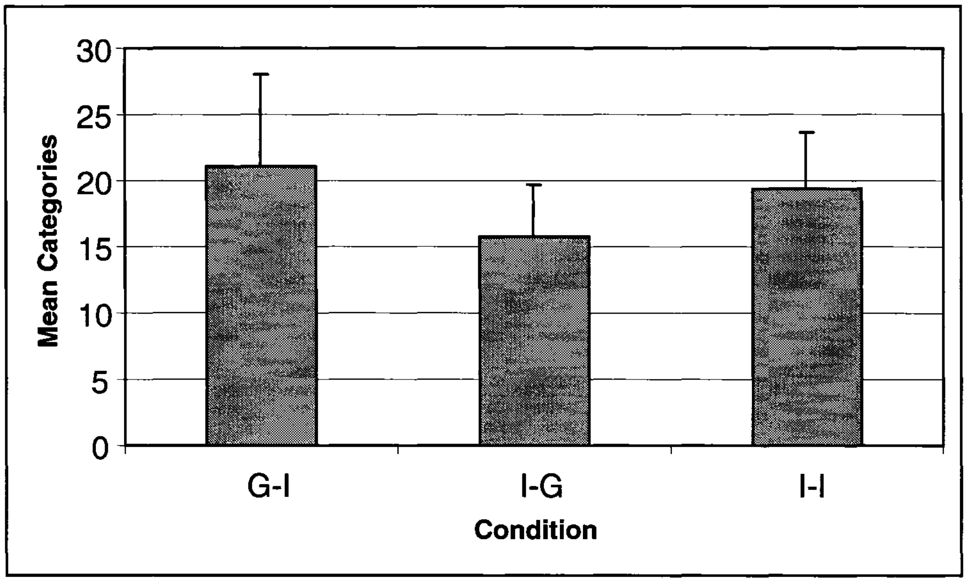

Figure 2. Mean Categories generated and Standard Deviation for each Condition across Sessions.

As seen in Figure 2, G-I produced the most categories and I-G produced the fewest; this difference approached significance, p=.075. I-I was not significantly different from I-G and G-I. Therefore, the interactive component, G, in a brainstorming session does not appear unequivocally to enhance the number of idea categories produced. Rather, interactivity appears to impair the generation of a wide variety of ideas (categories) when it occurs in the latter half of brainstorming. This was true for both the above indicators of creativity: number of ideas and number of idea categories. Although interactivity in the first half of brainstorming appears to enhance creativity compared to no interactivity, the difference was not statistically significant. Results for the other measures of creativity, number of elaborations / combinations and number of original ideas are presented next.

Interaction

For the interaction, both multivariate simple effects were significant. First the simple main effect for condition is presented then the simple main effect for session.

Simple Effect for Condition. The multivariate simple main effect for Condition was significant for Session 1 $F(2, 15) = 2.78$, $p<.05$ and Session 2 $F(2, 15) = 4.83$, $p< .01$. A simple main effect of Condition was only significant for the measure number of ideas in Session 1 $F(2, 15) = 4.87$, $p<.05$ and Session 2 $F(2, 15) = 11.70$, $p< .01$. The differences between the sessions for each condition are presented in Figure 3.

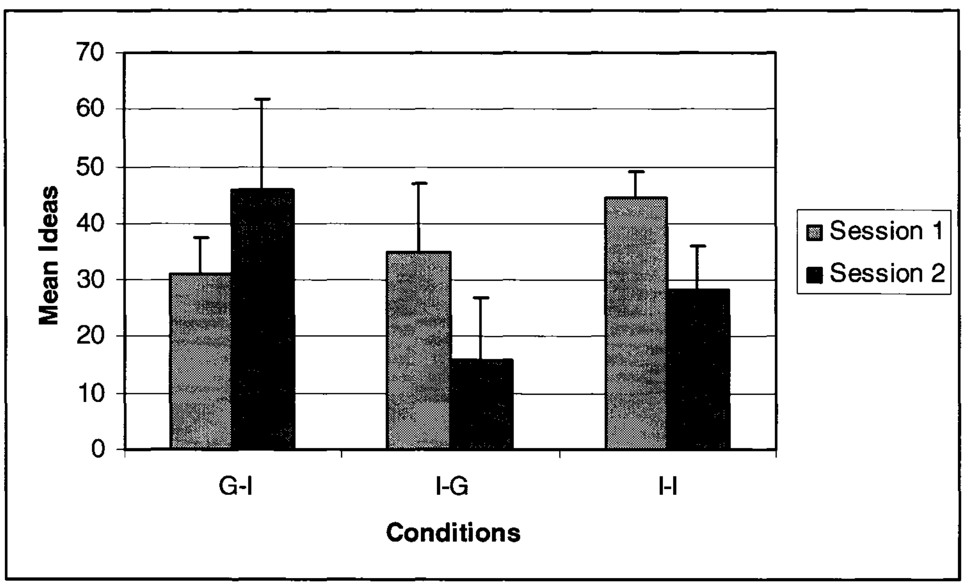

Figure 3. Mean number of Ideas and Standard Deviation for each Condition in each Session.

For Session 1, Figure 3 reveals that I-I generated the most ideas followed by I-G then G-I. Most of these differences were significant. I-I generated significantly more ideas than G-I, $p<.05$ and than I-G, $p< .05$. The difference between G-I and I-G was not significant. These findings partially support Hypothesis 1a, which predicted that I-I would result in more ideas than G-I. However, contrary to what was expected, differences between I-G and I-I were also detected. Possible explanations will be explored in the Discussion.

For Session 2, Figure 3 indicates that G-I generated the most ideas followed by, I-I then I-G. G-I did generate significantly more ideas than I-I, $p<.01$ and than I-G, $p<.001$ as predicted by Hypothesis 1b. This provides support that interactivity in Session 1 provided additional value that was displayed in Session 2 and that without such interactions a group did not produce as many ideas. Contrary, to what Hypothesis 1b predicted, the difference between I-G and I-I was not statistically significant. This finding supports the idea that delaying interactivity until Session 2 does not provide value but may impair idea generation.

Simple Effect for Session. The multivariate simple effect for Session was significant for G-I, $F(1,10) = 19.07$, $p< .001$; I-G, $F(1,10) = 4.99$, $p< .05$ and I-I, $F(1,10) = 7.40$, $p =.01$. A simple main effect of Session was significant for both measures. First, number of ideas will be reported followed by number of idea categories.

Simple Main Effect of Session for Number of Ideas. Figure 3 indicates that both I-G and I-I generated more ideas in Session 1 compared to Session 2; G-I however generated more ideas in Session 2 compared to Session 1. Notably, it is during the I phase that both hybrid sessions perform best. I-G generated significantly more ideas in Session 1 than in Session 2, $p<.01$. I-I generated significantly more ideas in Session 1 than in Session 2, $p<.01$. Unlike the other conditions, G-I generated significantly more ideas in Session 2 than in Session 1, $p<.001$.

Simple Main Effect of Session for Idea Categories. Differences in number of idea categories between the sessions for each condition are shown in Figure 4.

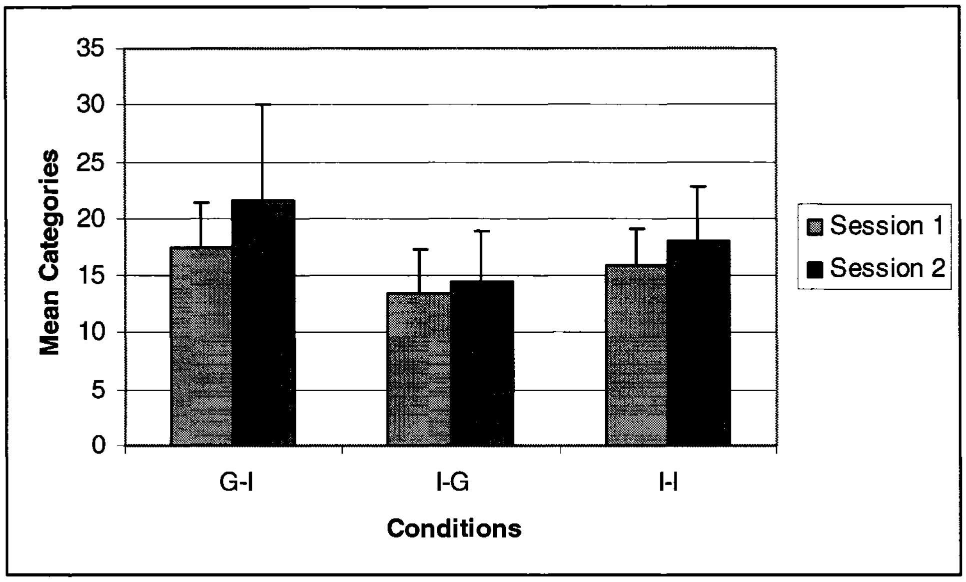

Figure 4 Mean Ideas generated and Standard Deviation for each Condition in each Session.

Figure 4 shows that all conditions generated slightly more idea categories in Session 2 compared to Session 1. For G-I, this difference was significant, $p<.01$. For I-I, it approached significance, $p=.052$, and for I-G it was not significant.

Number of Elaborations / Combinations

An exploratory analysis was conducted for the dependent variables Number of elaborations / combinations. A 3 x (2) mixed ANOVA for Condition (G-I, I-G, I-I) with repeated measures on Session (1, 2), to compare Number of elaborations / combinations, revealed a significant main effect for Condition $F(2, 30) = 112.85$, $p<.05$ and a significant interaction, $F(2, 30) = 20.00$, $p<.001$. First the pairwise comparisons are reported for the main effect and then the interaction.

Pairwise Comparisons for Condition

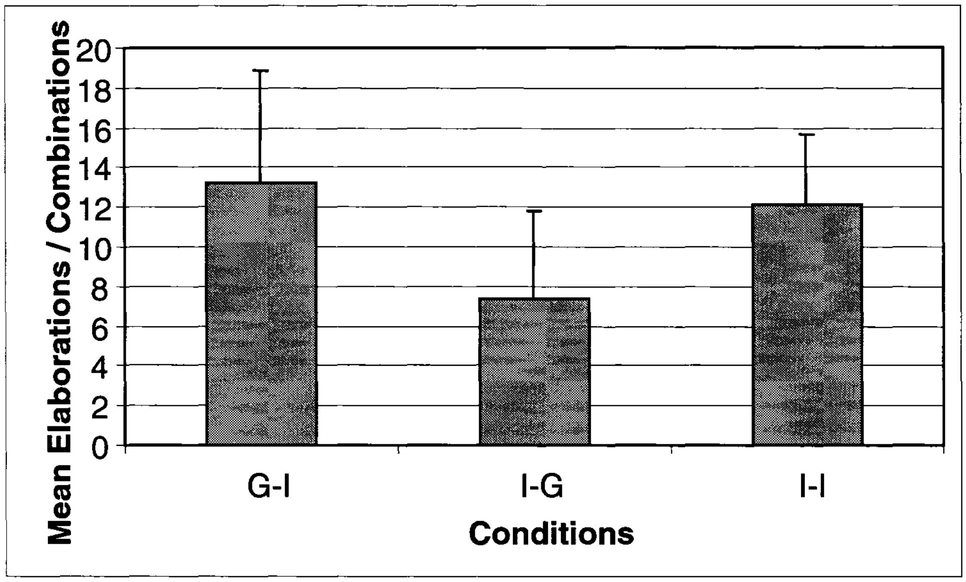

Figure 5. Mean Elaborations / Combinations and Standard Deviation for each Condition across Sessions.

Figure 5 shows that I-G produced the fewest elaborations / combinations followed by I-I then I-G. Pairwise comparisons were conducted and revealed that I-G generated significantly fewer elaborations / combinations than G-I, $p<.05$ and than I-I, $p< .05$. The difference between G-I and I-I was not statistically significant. The difference between G-I and I-G provides some support for Hypothesis 3, however, contrary to what Hypothesis 3 predicted, interactivity did not guarantee more elaborations / combinations. Rather, interactivity in the latter half of brainstorming is detrimental to the production of elaborations / combinations.

Interaction Condition x Session

Both the simple main effects for Condition and Session were significant. Pairwise comparisons were conducted to determine the locus of the effect. First the simple main effect for Condition is presented and then Session.

Simple Effect for Condition. The simple main effect for Condition was significant for Session 1 F (2, 15) = 3.80, p< .05 and Session 2 F (2, 15) = 12.39, p< .01. Differences among the conditions for each session are shown in Figure 6.

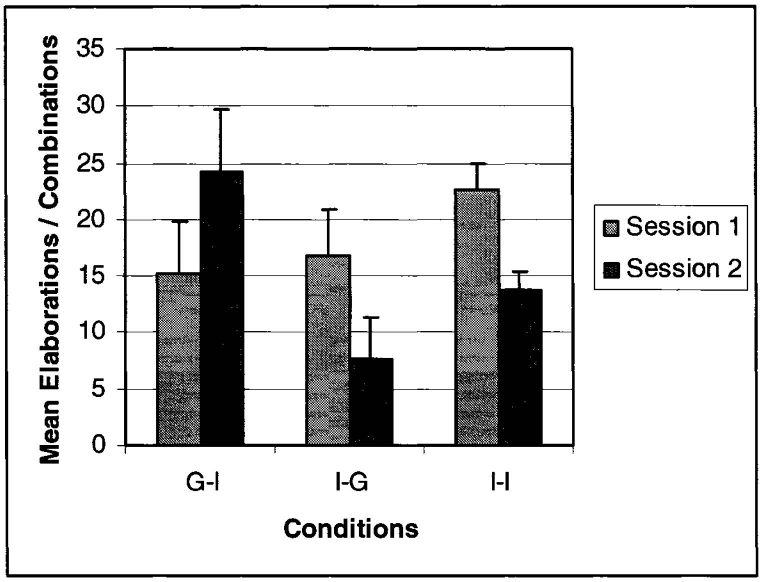

Figure 6. Mean number of Elaborations / Combinations and Standard Deviation for each Condition in each Session.

For Session 1, I-I generated the most elaborations / combinations followed by I-G then G-I. I-I generated significantly more elaborations / combinations than I-G, p< .05 and than G-I, p<.05. The difference between I-G and G-I was not statistically significant.

For Session 2, G-I generated the most elaborations / combinations followed I-I then I-G. G-I generated significantly more elaborations / combinations than I-I, p< .01 and than I-G, p<.001. The difference between I-I and I-G approached significance, p=.091.

Simple Effect for Session. The simple main effect for Session was significant for G-I,

F(1,10) = 16.82, p< .01; I-G, F(1, 10) = 9.93, p< .01; and I-I, F(1, 10) = 16.48, p< .01. Differences between the sessions for each condition are shown in Figure 6. Both I-G and

I-I generated more elaborations / combinations in Session 1 compared to Session 2. G-I, however, generated more elaboration / combinations in Session 2 compared to Session 1. It is notable that for both hybrid conditions, the most elaborations / combinations were generated in the non-interactive phase (I). I-G generated significantly more elaborations / combinations in Session 1 than in Session 2, $p<.01$. I-I generated significantly more elaborations / combination in Session 1 than in Session 2, $p<.01$. Unlike the other conditions, G-I generated significantly more elaborations / combinations in Session 2 than in Session 1, $p<.01$.

Number of Original Ideas

An exploratory analysis was conducted for the dependent variable Number of Original ideas. A 3 x (2) mixed ANOVA for Condition (G-I, I-G, I-I) with repeated measures on Session (1, 2), to compare Number of Original Ideas, revealed only a significant interaction, $F(2,30) = 23.53$, $p<.001$. To test Hypothesis 4, which predicts differences among the conditions across sessions, planned comparisons are presented next followed by the results for the interaction.

Planned Comparisons

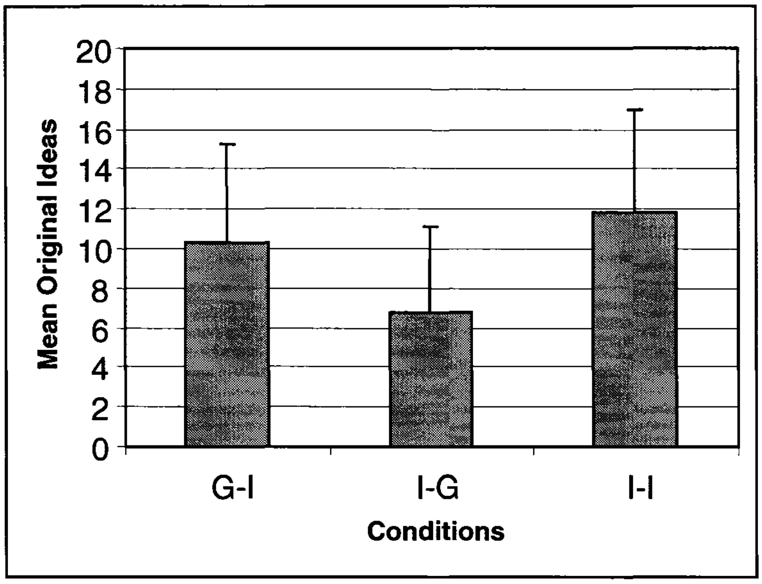

Figure 7. Mean number of Original Ideas and Standard Deviation for each Condition across Sessions.

Figure 7 shows that overall, I-I produced the most original ideas, followed by G-I then I-G. The difference between I-I and G-I was not statistically different. I-I produced significantly more original ideas than I-G, p>.05. The difference between G-I and I-G approached significance, p=.089. These findings refuted Hypothesis 4, which predicted that interactivity would increase the number of original ideas and that interactivity at the beginning of brainstorming would be most beneficial. Instead, interactivity at the beginning (G-I) was no better than no interactivity (I-I) and interactivity in the latter half of brainstorming (I-G) impaired the production of original ideas.

Interaction

Both the simple main effects for Condition and Session were significant. Pairwise comparisons were conducted to determine the locus of the effect. First the simple main effect for Condition is presented and then Session.

Simple Effect for Condition. The simple main effect for condition was significant for Session 1, F (2,15) = 6.71, p<.01 and Session 2, F (2,15) = 7.22, p<.01. Differences among the conditions for each session are shown in Figure 8.

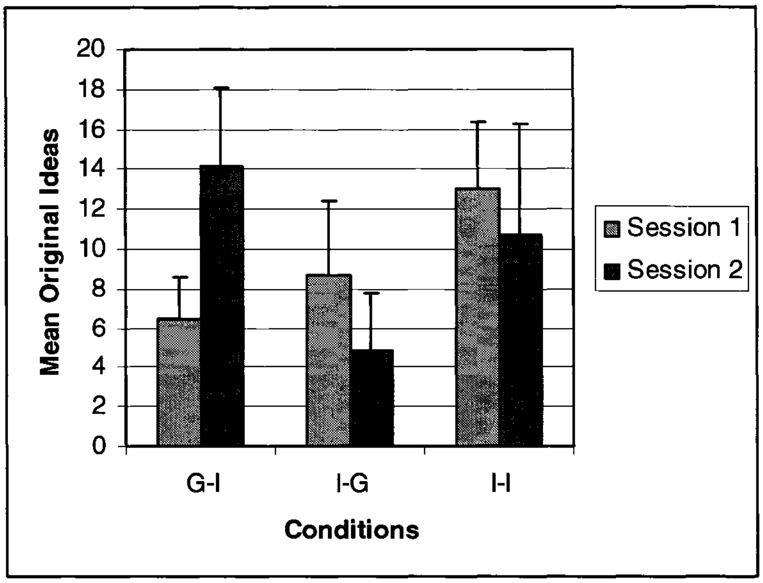

Figure 8. Mean number of Original Ideas and Standard Deviation for each Condition in each Session.

For Session 1, Figure 8 shows that I-I generated the most original ideas followed by I-G then G-I. I-I generated significantly more original ideas than I-G, p<.05 and than G-I, p<.01. The difference between G-I and I-G was not significant.

For Session 2, Figure 8 indicates that G-I generated the most original ideas followed by I-I then I-G. The difference between G-I and I-I was not significantly different. G-I generated significantly more original ideas than I-G, p<.01. I-I also generated more original ideas than I-G, p<.05.

Simple Effect for Session. The simple main effect for Session was significant for G-I, F (1,10) = 35.39, p<.001, I-G, F(1,10) = 8.85, p<.01 and approached significance for I-I, F (1,10) = 8.85, p=.09. As shown in Figure 8, I-G and I-I generated more original ideas in Session 1, whereas G-I generated more original ideas in Session 2. Notably, the hybrid conditions generated the most original ideas during the non-interactive phase (I). I-G generated significantly more original ideas in Session 1 than in Session 2, $p<.01$. I-I produced more ideas in Session 1 than in Session 2, this difference approached significance, $p = .09$. Unlike the other conditions, G-I produced significantly more original ideas in Session 2 than in Session 1, $p<.001$.

Quality

While the process of brainstorming generates many ideas the ultimate purpose is to increase the quality of ideas. To evaluate Hypothesis 6, which predicts that G-I should produce the highest quality ideas followed by I-G then I-I, an analysis of mean quality of ideas and an analysis of number of good ideas was performed.

Idea Quality

A 3 x (2) mixed ANOVA for Condition (G-I, I-G, I-I) with repeated measures on Session (1, 2), to compare Idea Quality, revealed only a significant interaction, $F(2, 30) = 8.60$, $p<.01$. To test Hypothesis 6, which predicts differences among the conditions across sessions, planned comparisons are presented next followed by the results of the Interaction.

Planned Comparisons.

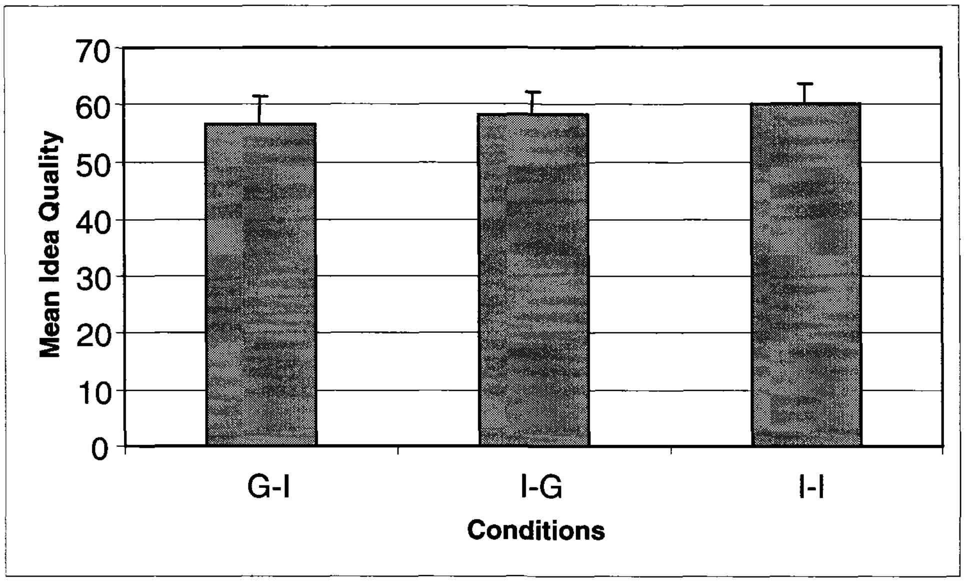

Figure 9. Mean Idea Quality and Standard Deviation for each Condition across Sessions.

Figure 9 shows that the conditions do not appear to differ greatly overall in the mean quality of ideas generated. I-I does appear to score highest followed by I-G then G-I. I-I did have a significantly higher mean quality score than G-I, $p<.05$. I-I and I-G did not produce significantly different mean quality ideas. This evidence refutes Hypothesis 6. Interactivity did not improve the mean quality of the ideas generated. Rather, interactivity at the beginning of brainstorming degrades the mean quality of ideas.

Interaction. Both the simple main effects for Condition and Session were significant. Pairwise comparisons were conducted to determine the locus of the effect. First the simple main effect for Condition is presented and then Session.

Simple Effect for Condition. The simple main effect for condition was only significant for Session 1 $F(2, 15) = 5.87$, $p<.05$.

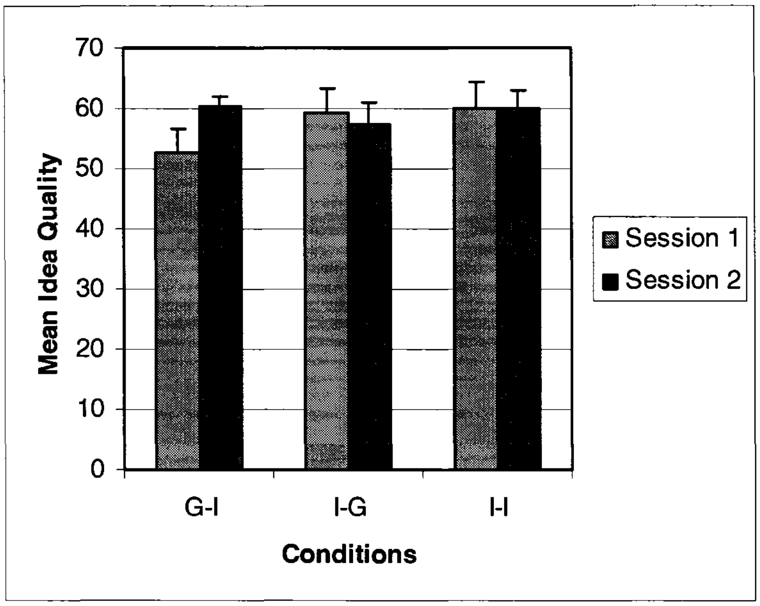

Figure 10. Mean Idea Quality and Standard Deviation for each Condition in each Session.

Differences in mean idea quality among the conditions for each session are shown in Figure 10. For Session 1, I-I produced the highest mean quality score, followed by I-G then G-I. The difference between I-I and I-G was not significant. I-I produced a significantly higher mean than G-I, $p<.01$. I-G also had a significantly higher mean score than G-I, $p<.05$. For Session 2, G-I had the highest mean score followed by I-I then I-G. G-I produced significantly lower mean quality ideas than I-I, $p<.01$ and than I-G, $p<.05$. I-I and I-G did not produce significantly different mean quality ideas.

Simple Effect for Session. The simple main effect for Session was only significant for: G-I, $F(1, 10) = 19.44$, $p< .01$. Figure 10 shows that G-I had a higher mean score in Session 2 compared to Session 1. Notably, this was during the non-interactive (I) phase.

Number of Good Ideas

Osborn's intended purpose of brainstorming was not only to produce more ideas but also more good ideas (1957). Although using mean quality scores is the traditional measure of quality, it obscures which conditions produced the most good ideas, which is the crux of brainstorming: to produce more good ideas. Thus, this section examines which condition produced the most ideas that received a high quality score of 80 points out of a possible 100.

A 3 x (2) mixed ANOVA for Condition (G-I, I-G, I-I) with repeated measures on Session (1, 2), to compare Number of Good Ideas, revealed only a significant interaction, $F(2, 30) = 13.60, p<.001$. To test Hypothesis 6, which predicts differences among the conditions across sessions, planned comparisons are presented next followed by the results of the interaction.

Planned Comparisons. Planned comparisons were conducted to determine across sessions which condition produced the most good ideas. No significant differences were found. Contrary to what Hypothesis 6 predicted, interactivity did not improve the number of good ideas generated. Both the simple main effects for Condition and Session were significant. Pairwise comparisons were conducted to determine the locus of the effect. First the simple main effect for Condition is presented and then Session.

Simple Effect for Condition. The simple main effect for condition was only significant for Session 2 $F(2, 15) = 6.34, p<.05$.

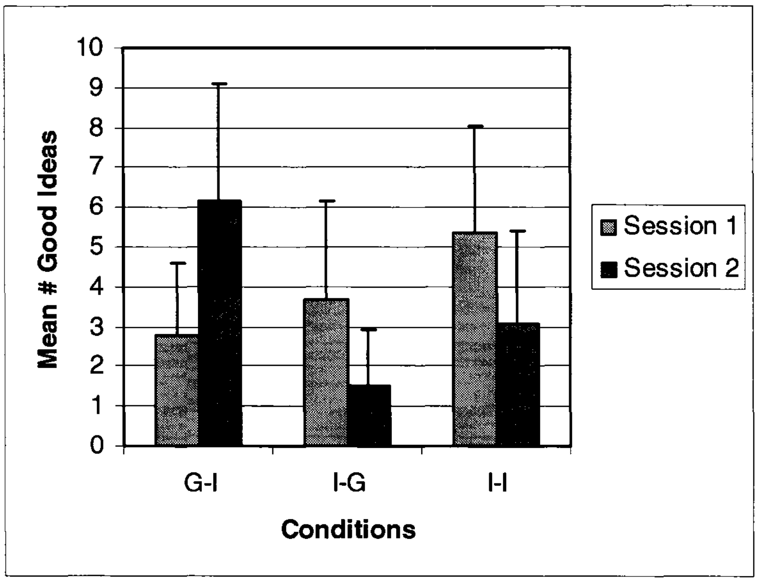

Figure 11. Mean Number of Good Ideas and Standard Deviation for each Condition in each Session.

As shown in Figure 11, for Session 2, G-I generated the most good ideas followed by I-I then I-G. G-I produced significantly more good ideas than I-I, $p<.05$ and than I-G, $p<.01$. I-I and I-G did not produce a significantly different number of good ideas.

Simple Effect for Session. The simple main effect for Session was significant for all three conditions. G-I produced more good ideas in session 2, $F(1, 10) = 14.86$, $p< .01$. This was reversed for I-G, $F(1, 10) = 6.09$, $p< .01$ and I-I, $F(1, 10) = 6.73$, $p< .05$, both of which resulted in more good ideas in Session 1 than in Session 2.

Participation

To achieve a deeper understanding of how the brainstorming conditions affect participation, Rate of Idea Generation, Interactions and Proportion of Participation were evaluated.

Rate of Idea Generation

The Chow test was conducted in order to determine if the rate of idea generation differed across groups. The Chow test assesses whether the set of linear regression parameters (i.e., the intercepts and slopes) is equal across groups (Chow, 1960) The dependent variable, cumulative number of ideas generated per minute, was determined for each group in each condition across sessions and in each session. The continuous predictor variable, Minute, was entered as a covariate and Condition as the predictor variable. This analysis was conducted both across sessions and within sessions. The interaction for Condition x Minute was significant across Sessions $F(2, 15) = 68.81$, $p<.001$ and for Session 1 $F(2, 15) = 25.31$, $p<.001$ and Session 2 $F(2, 15) = 46.14$, $p<.001$. First, the results across sessions is presented, followed by the results for Session 1 then Session 2.

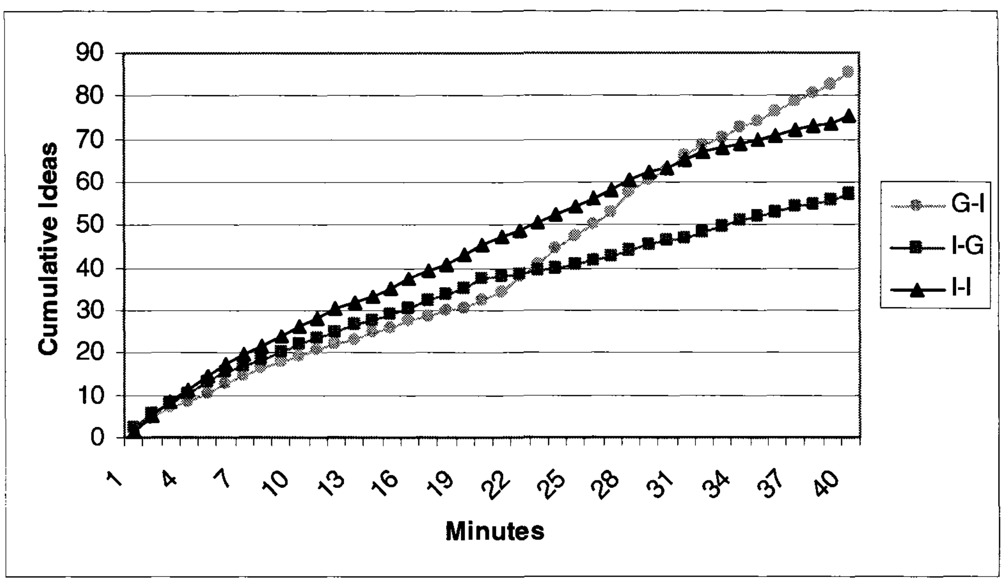

Figure 12.Rates of Idea Generation for each Condition across Sessions.

Figure 12 indicates that across Sessions, G-I had the highest rate of idea generation followed by I-I than I-G. G-I had a significantly higher rate of idea generation than I-I, p<.001 and than I-G, p<.001. I-I also generated significantly more ideas than I-G, p<.001. This indicates that interactivity followed by non-interactivity (G-I) improves the rate of idea generation compared to non-interactive brainstorming (I-I) while non-interactivity followed by interactivity (I-G) impedes the rate of idea generation compared to non-interactive brainstorming (I-I).

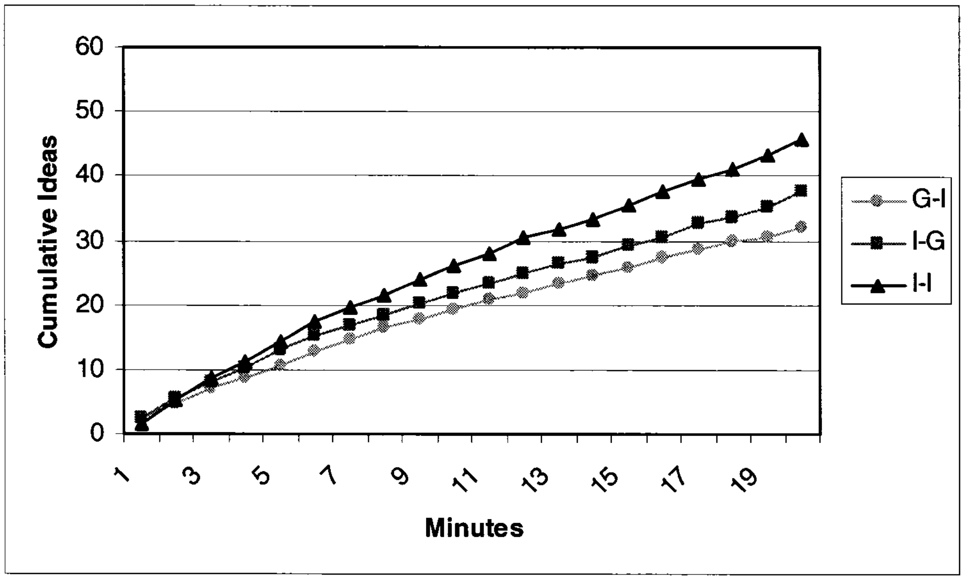

Figure 13.Rates of Idea Generation for each Condition in Session 1.

Figure 13 indicates that in Session 1, I-I had the highest rate of idea generation followed by I-G then G-I. I-I had a significantly higher rate of idea generation than I-G, p<.001 and than G-I, p<.001. I-G also generated significantly more ideas than G-I, p<.001. This indicates that interactivity was impairing the rate of idea generation.

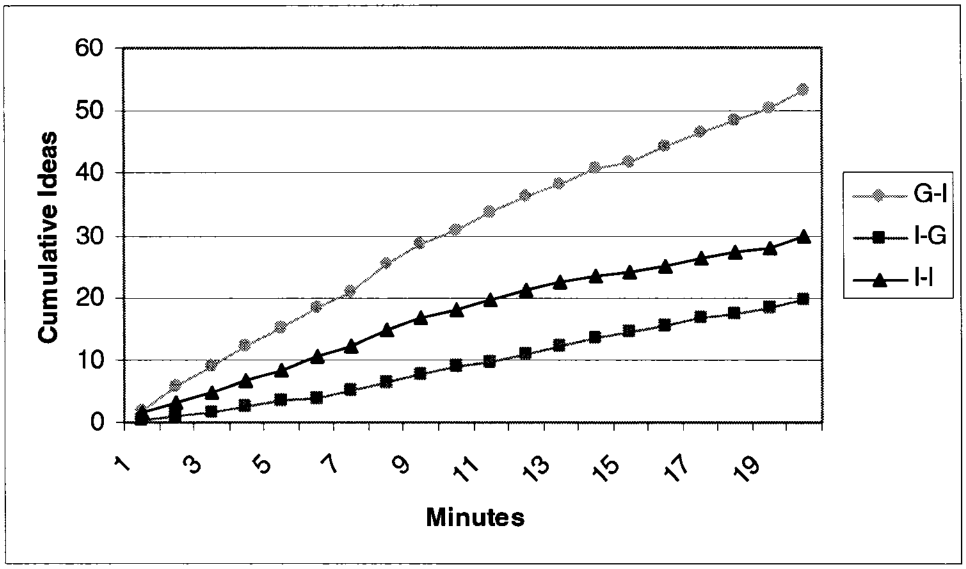

Figure 14. Rates of Idea Generation for each Condition in Session 2.

Figure 14 shows that the differences in rate of idea generation across conditions are different for Session 2 compared to Session 1. In Session 2, G-I had the highest rate of idea generation followed by I-I and I-G. G-I had a significantly higher rate of idea generation than I-G, $p<.001$ and than I-I, $p<.001$. I-I also had a significantly higher rate of idea generation compared to I-G, $p<.001$. These results indicate that during interactivity, the rate of idea generation is impaired compared to non-interactivity. Also, interactivity which precedes a non-interactive brainstorming session will result in a higher rate of idea generation compared to non-interactivity preceding a non-interactive brainstorming session.

Interactivity

The theoretical advantage interactive groups boast over non-interactive groups is the exchange of information. The results thus far indicate that interactivity at the beginning of brainstorming is more effective than interactivity at the end of brainstorming. To determine if order of the interactive and non-interactive session affected interaction among the group members, verbal exchanges among the group members were counted during the interactive (G) session and a t-test was conducted to compare the mean number of interactions between the hybrid conditions.

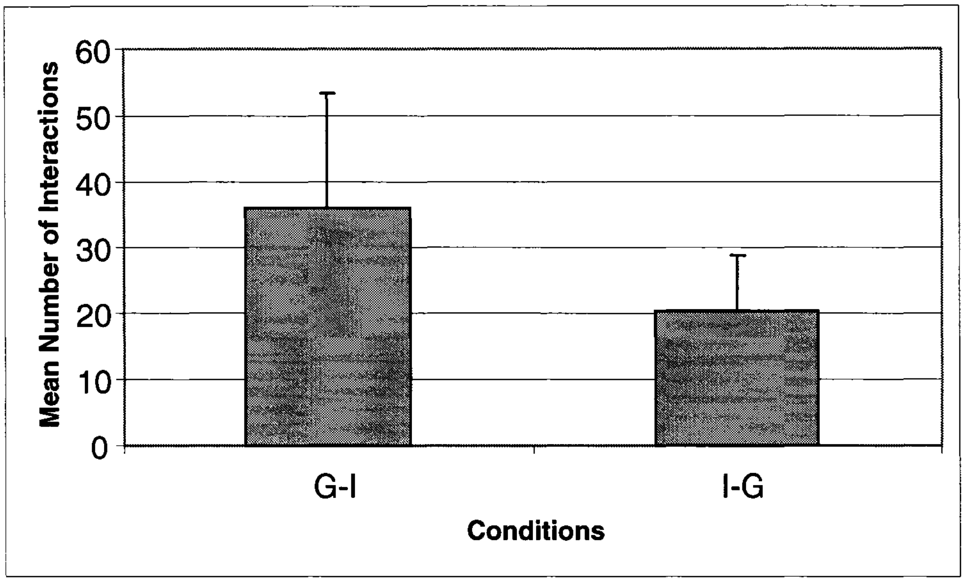

Figure 15. Mean Number of Interactions in the Interactive Session.

Figure 15 shows that G-I appeared to produce more interactions than I-G. This difference approached significance $t(10) = 2.04$, $p=.069$.

Proportion of Participation

To determine if group members contributed similarly across conditions the proportion of ideas each member contributed was computed. Participants were ranked as the highest, middle or lowest contributor for their own group. This was done for each group for each session and across sessions for the participants' proportion of contribution and hence ranking could change across sessions. First, the results across sessions is presented and then the results for Session 1 and Session 2.

Across Sessions. A 3 x 3 ANOVA for Condition (G-I, I-G, I-I) and Ranking (high, middle, low) for the dependent variable Proportion of Participation and collapsed across sessions was conducted. A significant main effect for Ranking, $F(2, 30) = 41.07$, $p<.001$

was revealed but not for the main effect of Condition or the Interaction. Therefore, the proportion of participants' contributions was similar across Conditions.

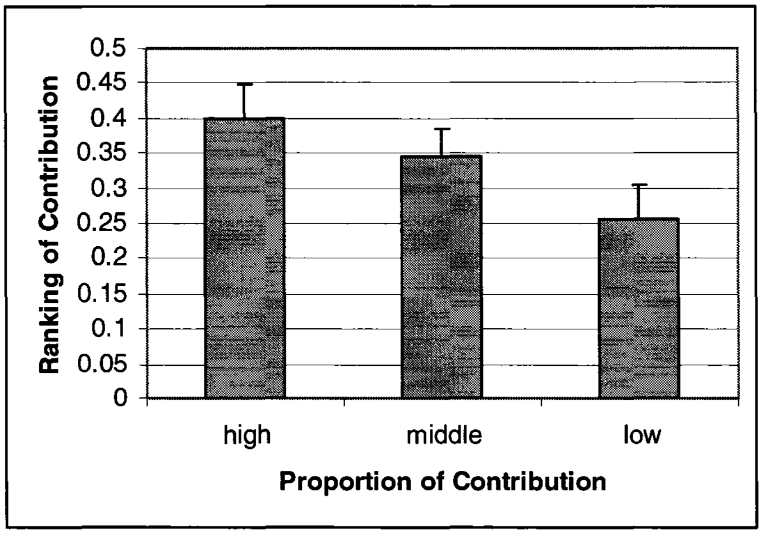

Figure 16. Proportion of Contributions for each group member across sessions.

Figure 16 shows that there are differences in the proportion of contributions across group members. The difference between the highest contributor and the middle contributor was significant, $p<.001$ as was the difference between the highest contributor and the lowest contributor, $p< .001$. The difference between the middle and lowest contributors was also significant $p<.01$.

Session 1. A 3 x 3 ANOVA for Condition (G-I, I-G, I-I) and Ranking (high, middle, low) for the dependent variable Proportion of Participation was conducted for Session 1. A significant main effect for Ranking, $F(2, 30) = 68.10$, $p<.001$ was revealed but not for the main effect of Condition or the Interaction. Therefore, the proportion of participants' contributions was similar across Conditions for Session 1.

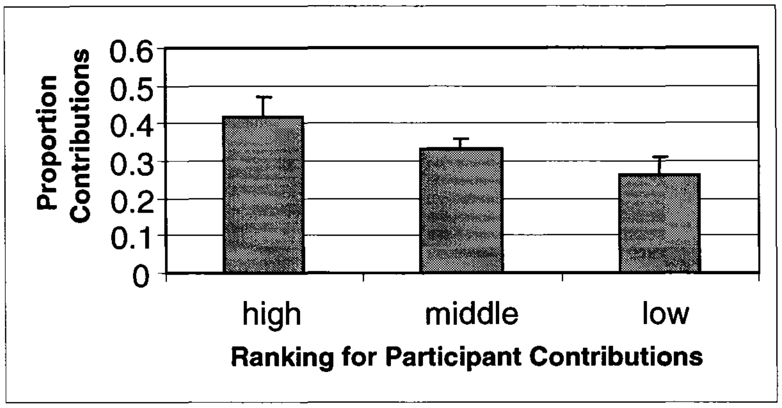

Figure 17.Proportion of Contributions for each group member in Session 1.

Figure 17 shows that there are differences in the proportion of contributions across group members. The highest contributors accounted for significantly more ideas than the middle contributors, p<.001 and the lowest contributors, p< .001. The difference between the middle and lowest contributors was also significant p<.001.

Session 2. A 3 x 3 ANOVA for Condition (G-I, I-G, I-I) and Ranking (high, middle, low) for the dependent variable Proportion of Participation was conducted for Session 2. A significant main effect for Ranking, F (2, 30) = 68.10, p<.001 was revealed but not for the main effect of Condition or the Interaction. Therefore, the proportion of participants' contributions was similar across Conditions for Session 2.

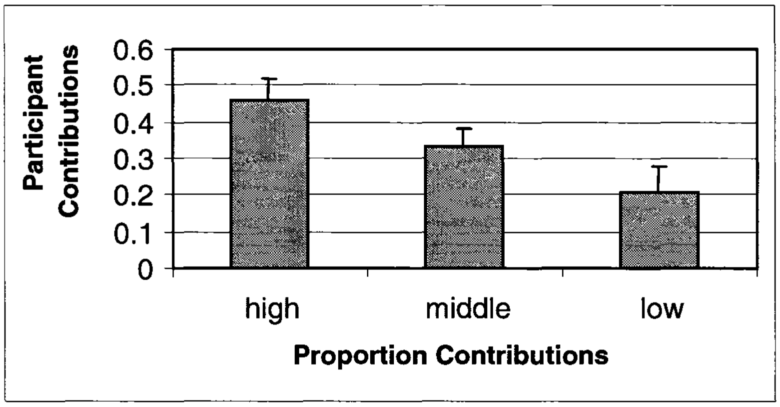

Figure 18. Proportion of Contributions for each group member in Session 2.

Figure 18 shows that there are differences in the proportion of contributions across group members. The highest contributors accounted for significantly more ideas than the middle contributors, $p<.001$ and the lowest contributors $p< .001$. The difference between the middle and lowest contributors was also significant $p<.001$.

These results indicate that group members do not contribute equally; however, these differences are consistent across Conditions. For a complete summary of the results refer to Table 6 and Table 7.

Table 6.
Predictions and Results of brainstorming performance across conditions, G-I, I-G and I-I for Hypothesis 1 through 6.

	Predictions	**Raw Data**	**Significance**
Hypothesis 1 Number of Ideas	**G-I > I-G > I-I**	**G-I > I-I > I-G**	**G-I > I-G****
			I-I > I-G*
Hypothesis 1a Number of Ideas Session 1	**(I-G = I-I) > G-I**	**I-I > I-G > G-I**	**I-I > G-I***
			I-I > I-G*
Hypothesis 1b Number of Ideas Session 2	**G-I > I-I > I-G**	**G-I > I-I > I-G**	**G-I > I-I****
			G-I > I-G***
Hypothesis 2 Number of Categories	**G-I > I-G > I-I**	**G-I > I-I > I-G**	**G-I > I-G[a]**
Hypothesis 3 Number of Elaboration / Combinations	**G-I > I-G > I-I**	**G-I > I-I > I-G**	**G-I > I-G***
			I-I > I-G*
Hypothesis 4 Number of Original Ideas	**I-G > G-I > I-I**	**I-I > G-I > I-G**	**I-I > I-G[a]**
			G-I > I-G*
Hypothesis 5 Creativity	**G-I > I-G > I-I**	**G-I > I-I > I-G**	**N / A**
Hypothesis 6 Quality	**G-I > I-G > I-I**	**Mean:**	
		I-I > I-G > G-I	**I-I > G-I***
		Total No.	
		G-I > I-I > I-G	**No Difference**

[a] indicates that the results are approaching significance (.05<p<.1), * indicates p<.05; ** indicates p<.01; ***indicates p<.001

Table 7.

Results of brainstorming attributes for conditions, G-I, I-G and I-I

Dependent Variable	Raw Data	Significance
Rate of Idea Generation across Sessions	**G-I > I-I > I-G**	**G-I > I-I*** **
		G-I > I-G* **
		I-I > I-G* **
Rate of Idea Generation Session 1	**I-I > I-G > G-I**	**I-I > I-G*** **
		I-I > G-I* **
		I-G > G-I* **
Rate of Idea Generation Session 2	**G-I > I-G > I-I**	**G-I > I-G*** **
		G-I > I-I* **
		I-G > I-I* **
Interactivity	**G-I > I-G**	**G-I > I-G**[a]
Proportion of Participation		**None**

[a] indicates that the results are approaching significance (.05<p<.1), * indicates p<.05; ** indicates p<.01; ***indicates p<.001

Discussion

Brainstorming non-interactively then interactively (I-G) is a method commonly used among practitioners, as participants can generate ideas in advance to discuss during group brainstorming. To date, however, little empirical research has supported its theoretical advantages (Paulus, et al., 1995). Although Paulus, et al., (1995) and Leggett, et al., (1996) have compared performance for this hybrid method (I-G) to its counterpart, G-I, no previous studies have compared these hybrid conditions to the traditionally used non-interactive (I-I) brainstorming. The hybrid conditions involving both interactive and non-interactive sessions (I-G and G-I) in the present study enabled determination of overall effects of conditions. In particular, it was of interest to learn 1) if an interactive component provides some added value to brainstorming performance over no interaction and 2) if the order of interactivity and non-interactivity has any effect. The results indicate that an interactive brainstorming component can affect performance compared to no interactive component and that the impact does relate to the order of interactivity and non-interactivity. Brainstorming non-interactively following an interactive session (I-G) hinders performance compared to the reverse order (G-I) or no interactive brainstorming component (I-I). Although groups who brainstormed interactively followed by non-interactively (G-I) consistently out-performed non-interactive (I-I) groups, this study did no find any significant difference between these conditions. This may have been the result of a small sample size.

Next, the main findings that relate to creativity, then to quality, are discussed followed by the theoretical implications of these findings. Modifications to the Semantic Network cognitive model are made to address the differences between the predicted findings and the actual results. Based on the findings, recommendations are made regarding brainstorming, future work is discussed, and a conclusion is presented.

Creativity

According to Wallas (1926) successful problem solvers produced creative solutions. In order to assess creativity four measures were used that correspond to Guilford's (1967) definition of creativity, names: number of ideas, number of idea categories, number of combinations / elaborations and number of original ideas. The results showed a consistent pattern across these measures, which, taken together, can be used to extrapolate an overall pattern of creativity across conditions. It is important to note that although a consistent pattern was detected across measures (i.e., G-I > I-I > I-G) only certain differences were statistically significant (i.e., G-I < I-G and I-I > I-G). Although G-I consistently outperformed I-I, this difference was not statistically detected and may be due to the small sample size.

Sample Size

The sample size used in the formal study was determined to have sufficient power as to detect an effect size based on the one previously found by Paulus and colleagues (2001) who detected a large and robust difference between G-I and I-G, where G-I produced more ideas than I-G. As no previous studies have compared these hybrid conditions with a non-interactive (I-I) condition however, an effect size was estimated. The selected cell size ($n = 6$) may have been too small to have detected differences in the formal study between G-I and I-I. Notably, in the formal study the differences between G-I and I-G was quite sizeable and statistically detected; a larger sample size and hence more power may be required to detect the more moderate difference between G-I and I-I and thus show that interactive brainstorming followed by non-interactive brainstorming (G-I) results in superior performance to solely non-interactive brainstorming (I-I).

Findings

Although the difference between G-I and I-I's performance was not statistically significant, the moderate difference was persistent across measures with the exception of the number of original ideas, suggesting that the differences between G-I and I-I may increase with additional power. Although the above results did not yield a robust advantage to brainstorming interactively initially, statistically, they suggest that interactivity at the beginning of brainstorming does not hamper performance compared to no interactivity. These results also indicate that brainstorming procedures affect the different measures of creativity (i.e., number of ideas, number of idea categories, number of combinations / elaborations and number of original ideas) in a similar manner. The above results suggest that interactivity does not guarantee superior performance: an interactive brainstorming component can be beneficial or detrimental to performance compared to non-interactive brainstorming depending on when interaction occurs. Groups who brainstormed interactively in the first session (G-I) tended to perform somewhat better than non-interactive groups (I-I), and those who brainstormed interactively in the last session (I-G) tended to perform most poorly. These results indicate that brainstorming non-interactively first and interactively second (I-G), is not ideal. This expands on Paulus and colleagues' (2001) work by showing that I-G brainstorming is not advantageous compared to G-I or I-I. Possible explanations for this finding are discussed later in the section on Theoretical Implications. The pattern of results indicate that G-I was the most creative followed by I-I then I-G but the difference between G-I and I-I may not be significant. This contradicts the prediction that both hybrid conditions would outperform the non-interactive condition. Therefore, hypothesis 6 was rejected. Finally, it is also important to note that I-I generated more ideas than I-G in Session 1. This finding was unexpected as there were no procedural differences between the two conditions in Session 1. These differences could be attributed to individual differences in group composition such that differentially affected I-G and I-I.

Quality

The purpose of brainstorming according to Osborn (1957) is to generate more ideas, which should lead to the production of more good ideas. Presumably groups who are more creative produce better solutions (Wallas, 1926). In order to test this, quality was assessed here. Traditionally, mean quality scores have been used to compare performance (e.g., Valacich, Dennis and Connolly (1994), and Barki and Pinsonneault (2001)) and as such it was used here. Using the mean, however, only provides a measure of the central tendency of quality and thus does not provide any true indication as to the number of good ideas produced. In an effort to avoid this undesirable effect, the number of good ideas was also used here. The findings that both measures yielded are starkly different. The non-interactive groups (I-I) had the highest mean scores, followed by I-G then G-I. Statistically, only interactivity at the beginning of brainstorming (G-I) proved detrimental to the mean idea quality compared to baseline (I-I). This pattern contradicts that found for most other measures. This finding refutes Osborn's claim that more ideas will result in more good ideas.

By the same token, Osborn did argue that more good ideas would be produced, not an overall higher average quality of ideas, which is what mean quality scores actually evaluate. When the number of good ideas was analysed, the pattern of results radically shifted, showing that G-I produced the most good ideas followed by I-I, then I-G. This finding indicates that the more creative condition also produced more good ideas. Although the differences did not reach a level of statistical significance, the pattern of results suggests that Osborn's claim is correct and that creativity and idea production corresponds with the production of more good ideas. The theoretical impact of these findings is discussed next.

Theoretical Implications

The development of Osborn's brainstorming process was guided by the theoretical principle that individuals who interactively work together should produce more ideas and better ideas than individuals who work alone (Osborn, 1957). Empirical research has consistently shown the reverse to be true (Van de Ven & Delbecq, 1971; Bouchard & Hare, 1970; Lewis, Sadosky & Connolly, 1975). These findings have brought to light process losses which have been shown to affect performance (Steiner, 1972). As previously discussed, modifications to the brainstorming process to counteract process losses have resulted in comparable performance between interactive groups and non-interactive groups (see Madsen & Finger, 1978; Price, 1985; Valacich, Dennis & Connolly, 1994). The hybrid brainstorming procedure combines interactive session with non-interactive sessions to garner the benefits of both processes rather than attempting to mitigate process losses. As discussed earlier, little research has investigated hybrid brainstorming methods and the impact of restricting interactivity to the beginning of a brainstorming session compared to the impact of restricting interactivity to the end of a brainstorming session. Some research suggests that the impact of interactivity changes depending on when it occurs in a brainstorming session; however, research which has compared hybrid brainstorming conditions, I-G and G-I, have had mixed findings (Leggett, Putman, Roland & Paulus, 1996; Paulus, Larey & Ortega, 1995). The present study reproduced Paulus and colleagues' (2001) findings that interactivity at the beginning of brainstorming resulted in better performance compared to interactivity at the end of brainstorming. To date, the performance of hybrid brainstorming has not been compared to non-interactive brainstorming, which has traditionally been the baseline for comparison. This comparison is important as it provides a means of determining if interactivity is beneficial compared to non-interactivity. Contrary to what was expected, the hybrid conditions did not outperform the non-interactive one. Thus, this comparison (between hybrid and non-interactive brainstorming) refuted Osborn's (1957) claim that interactivity is beneficial. Next, explanations for the unexpected findings are discussed.

Semantic Network Cognitive Model

The semantic network cognitive model for brainstorming correctly predicted differences between the hybrid brainstorming conditions in favour of G-I. It was noted that interactivity and hence exposure to others' ideas provides the potential to generate more ideas. This notion is supported when examining the performance of the conditions between sessions. For I-G and I-I performance on most measures typically declined in Session 2. The reverse was true for G-I, where performance was consistently higher in the Session 2 compared to Session 1. Therefore the cognitive model allows for predictions about the relative impact of different conditions. The model, however, does not account for the availability of opportunity (or time) to realize the potential. According to the model, I-G groups have more potential compared to I-I, as they are exposed to more ideas from other group members. This exposure to others' ideas, however, creates additional process losses as members typically first review their group members' ideas before generating more ideas. As a result, these individuals have less opportunity to generate more new ideas compared to G-I groups. G-I groups can immediately begin generating ideas and interacting during the interactive component as they do not have any prior ideas to review. Although G-I groups are not exposed to as many ideas from other members (less potential) they have the remainder of the brainstorming session to generate ideas independently (more opportunity). If process losses were impacting I-G differently during the interactive component compared to G-I then differences in the number of interactions, as defined by verbal exchanges between or among group members during the interactive session, between the two conditions would be found. The difference in the number of interactions between I-G and G-I approached significance, supporting the idea that I-G encounters greater process losses compared to G-I.

As mentioned earlier, Osborn (1957) argued that interactivity should be beneficial compared to non-interactivity. The cognitive model supports this in that interactivity provides more potential to generate new ideas; however, it necessarily reduces the opportunity to realize the potential as a result of process losses. Therefore, the potential to generate new ideas that is provided by interacting will only be beneficial in instances where ample opportunity is provided to realize the potential. The model predicted that both I-G and G-I should outperform I-I as the hybrid methods both provide the potential to generate new ideas (that I-I does not) combined with the opportunity to realize this potential to varying degrees. Although the difference was not significant, G-I slightly outperformed I-I; however, contrary to the model's prediction, I-G did not out-perform I-I. Presumably, I-G did not have sufficient opportunity to realize the added potential offered from the interactive session. An additional non-interactive session (I-G-I) may prove beneficial. More research is required to investigate the effect of interchanging interactivity and non-interactivity repeatedly. The results indicate that the semantic network cognitive model alone is insufficient to predict brainstorming performance. Rather the model in combination with consideration of process losses can be used to determine the potential among brainstorming conditions and the available opportunity to realize the potential.

Multidisciplinary Groups

Another reason why the hybrid conditions did not outperform the non-interactive condition could be that the groups were composed primarily of first year undergraduate students who arguably did not have diverging expertise. Interactivity is theoretically most beneficial when individuals can combine their knowledge. According to the cognitive model, this benefit should be most evident in instances where individuals have diverging expertise as this provides more potential to combine or elaborate on ideas and to stimulate more new ideas in others.

Problem Solving

As discussed, successful problem solvers are creative as defined by the solutions they produce. The present study found that the most creative conditions produced twice as many good ideas as the least creative condition. Although these differences were not statistically significant, arguably the difference may be practically significant.

It is important to consider the context in which brainstorming occurs. Practical considerations include the number of desired solutions, the homogeneity of the group members, if members are co-located, and if members are independent contributors or are required to work interactively. Recommendations and suggestions for different working contexts are discussed in the next section.

Idea generation is only one of many stages in problem solving. The success of any given idea is ultimately dependent upon the problem having been correctly identified, and the best idea selected. Although creativity did not impact the number of good ideas generated, it may impact problem identification or idea selection. As successful problem solving is dependent upon, problem identification, idea generation and idea selection, more research is required to understand the relationship between creativity and the other stages of problem solving.

Recommendations and Suggestions

The present study examined small groups whose members shared similar expertise. For comparable groups, the cost of bringing together collocated individuals to brainstorm interactively may not be beneficial and so far no empirical research has found interactivity to be more beneficial than non-interactivity for small groups, therefore these groups should brainstorm non-interactively (I-I). Note that this study used groups consisting of only three members. It is unknown how brainstorming performance for I-G, G-I and I-I will compare for larger groups. To date, only EBS has produced more ideas than non-interactive brainstorming for larger groups of nine, 12 or 18 (Valacich, et al., 1994). Furthermore, EBS does not require that group members be collocated. Therefore, for larger groups of collocated and non-collocated members, EBS is recommended.

In contexts that require multiple solutions such as marketing and advertising, the practical difference in number of good ideas produced is important. In such cases, the more creative brainstorming conditions (G-I and I-I) should be employed as this study showed that these conditions may produce more good ideas. In instances where individuals are expected to work together during or after idea generation, these groups should work interactively earlier rather than later and interactivity should be alternated with periods of non-interactivity (G-I).

Additional research is required to better understand the relationship between different group characteristics (e.g., expertise) and brainstorming procedures. The formal study did not investigate multidisciplinary groups; however, the semantic network cognitive model predicts that for these groups, G-I would result in greater creativity and specifically would produce more ideas and more good ideas compared to I-G and I-I.

Limitations of the Study

Previously, some limitations concerning the study have been noted and as such require that future work be conducted. These limitations are addressed here. The study used a small sample size (N = 18). A larger sample size is required to determine if the persistent moderate differences between I-I and G-I are reliable and statistically significant. Also, any individual differences or selection bias may be reduced with a larger sample size. As a result, the difference between I-I and I-G in Session 1 may cease to be significant. Furthermore, the participants' expert knowledge was homogenous. As discussed, future work is required to understand how the results differ for multidisciplinary teams. Finally, the results have shown that interactivity is best followed by non-interactivity. It is possible that brainstorming initially, non-interactively (I) may be superior to beginning interactively (G) if the initial non-interactive group is given a second non-interactive session following interactivity (I-G-I). Also, it may be beneficial to brainstorm in multiple G-I e.g., G-I, G-I, G-I. More work is required to understand the impact of alternating between interactive and non-interactive sessions.

Conclusion

This study provided a comparison of hybrid brainstorming to the standard measure of brainstorming performance, non-interactive brainstorming. Additionally, this study has also contributed to the brainstorming literature in providing new measures for brainstorming performance, which relate to creativity. The results showed that interactivity impairs performance compared to non-interactive brainstorming (I-I) when interactivity follows a non-interactive brainstorming session (I-G). Conversely, interactivity does not impede performance compared to non-interactive brainstorming (I-I) when it precedes non-interactivity (G-I). Also, the problem of assessing quality with means was identified and a better measure for assessing quality was provided, number of good ideas. The results offer some evidence that generating more ideas does not necessarily result in more good ideas. Finally, a new method of predicting performance has been proposed which incorporates the impact of process losses in conjunction with a new cognitive model, which assess potential success.

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Anonymity/Confidentiality: The data collected in this study will be kept confidential. We take special precautions to make sure that no one else will be able to identify you and what your responses were. All data will be coded so your name is not associated with your work. Your responses will be used for research purposes and only the principal researcher and her assistants will have access to data.

Right to Withdraw from the interview and experiment: Your participation in this study is entirely voluntary. You have the right to withdraw from this study at any time

<u>Participant's Signature</u>

I have read the above description of the study entitled Creativity and Quality in Idea Generation. I understand the conditions of my participation. My signature indicates that I agree to participate in the experiment.

Name(please print): ________________________

Signature: ________________________

Experimenter's name: Karen Philp______________

Experimenter's Signature: ________________________

Date: (dd/mm/yy): __/___/___

(Distribution: 1 copy to participant, 1 copy for files)

APPENDIX B

Participant Information

Please fill out the following information. All information you provide will be kept strictly confidential.

Name: ______________________________________

Sex: F / M

Age: _____

First Language:___________

Second Language: ___________

Years of Education: ___________

Experience with Brainstorming:
a) No Prior Experience
b) 1 – 10 times before
c) 10 – 20 times before
d) 20+

Experience with group work/group discussions
a) No Prior Experience
b) 1 – 10 times before
c) 10 – 20 times before
d) 20+

Hobbies:
____
____
____
____
____
____

APPENDIX C

Brainstorming Guide

Welcome to the brainstorming session. The purpose of this session is to brainstorm ideas for the piece of software we are going to be designing for students visiting the Antarctica. The session will consist of two phases. During the first 20-30 minutes you will be asked to generate as many ideas as possible with respect to what content should be included for the students. Half of this time will be spent generating ideas individually after which you will share your ideas with your group. The other half of the time will be spent generating ideas with your group. Please write out your ideas on the provided paper. Please do not evaluate any of the ideas put forth at this point and try and generate as many as possible. Please read the scenario below to get an idea of what students experience before visiting, while visiting, and after visiting the Antarctic.

Scenario/description of what "Students on Ice" do before visiting the Antarctic:

SOIers (Students On Ice participants) are given a lot of information and research tasks related to Antarctica before they go on the expedition. The more information they read and tasks they complete the better prepared they are for the trip: the lectures and activities. However, SOIers have little time (and motivation) to do the reading and research, as they are busy with classes in addition to working part-time jobs and trying to raise money for the trip. Currently, students are given nine educational units and activities about Antarctica which include: an introduction to the Antarctic, flora and fauna, Antarctic explorers, geomorphology, the politics of Antarctica, ice, Canadian Space Agency, human activity in Antarctica, global climate change and science in Antarctica. The accompanying exercises for each topic currently have SOIers do four tasks: exploration, concentration, speculation and personalization. The exploration component directs SOIers to other sources for information on the given topic and asks them to focus on a specific example to research in greater depth. For example, in the flora and fauna unit SOIers are asked to select birds, penguins, seal and whales they would most like to see and to familiarize themselves with some of their most distinguishing features. The concentration component requires students to further specialize their information. For example, in flora and fauna, SOIers are asked to select one animal to be their special connection with Antarctica and to become familiar with that animal's abilities that allow it to survive in the harsh Antarctic climate. Note, information they would like to know about the animal and were unable to find. For the speculation component SOIers are required to think and provide possible explanations or predictions regarding the topic. For example, in the flora and fauna section, SOIers are asked to contemplate why there are only 2 species of flowering plans while the remaining flora are mosses and lichens. They are instructed to contemplate the changes that have occurred in other parts of the world and write an outline describing the types of fossil evidence that one may find or expect to find within rocks in Antarctica. The personalization activity assists SOIers in recording their trip and provides tips with regard to the type of information they should record and how they should record it.

After the expedition to Antarctica most SOIers are required to give presentations about the expedition to various community groups as part of their fundraising arrangements.

What features should the interface have in order to facilitate learning and preparing their presentation?

APPENDIX D

Information Packet

Below is a copy of the current 4th unit: Exploration

UNIT #4 - EXERCISES

1. EXPLORATION:

This exploration will help you to begin to understand the development and distribution of the surface features of Antarctica.

A good reference book to use is entitled: Antarctica: the extraordinary history of man's conquest of the frozen continent: Reader's Digest (1990). You will also find Lonely Planet's book, Antarctica, a valuable overview, as well.

Antarctica was once part of the ancient super continent of Gondwana, so searching for this name will give you information on the continent about 200 million years ago.

Activity:
Find which other continents were also part of Gondwana and approximately when this drifting apart began to occur.

Using this as a starting point, outline three other significant changes that occurred to give Antarctica its current geomorphology (perhaps note the repercussions of continental drift, in terms of surface processes) and include approximate time references i.e. 65 million years ago.

2. CONCENTRATION:

You will visit the part of Antarctica known as the Antarctic Peninsula. Now that you are becoming familiar with the general structure of this wonderful continent, it is a good time to focus in on the area that you will be experiencing.

Activity:
Using a good map of Antarctica and the Southern Ocean, locate the following places:

South Georgia Island
Mount Erebus on Ross Island
Deception Island
Gerlache Strait
King George Island

Which types of rock will be most prevalent on the Peninsula? Why?

3. SPECULATION:

These magnificent mountains may contain minerals such as gold, silver, rubies, topaz and other deposits. This would make them very attractive to many countries and multinational concerns seeking to enrich their economies.

Activity:

Since the Protocol on Environmental Protection, signed in Madrid in 1991, this type of mining activity has been prohibited. Those who have signed the Protocol represent 80 percent of the world's population. In a page or less, depict your view of Antarctica, today and in the future, had this Protocol and the Antarctic Treaty not existed.

4. PERSONALIZATION:

You will see many amazing sights, and will be overwhelmed by the incredible vistas about you. A little extra research, now, will greatly enrich your observations.

Activity:

Study the appearance and characteristics of some common natural rock types, like igneous,
sedimentary and metamorphic. Then you will be better prepared to take pictures, make brief notes or draw sketches when you recognize such deposits.

Below are a list of links that lead to each exercise unit:
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=72
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=74
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=76
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=78
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=80
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=82
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=84
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=86
http://www.studentsonice.com/index.php?module=ContentExpress&func=display&ceid=88

APPENDIX E

Instructions for Formal Study

I-I

Instructions for first session

Welcome to the brainstorming session. The session will consist of two 20-minute brainstorming sessions where you will be brainstorming by yourself. After the first 20 minutes you will be given a brief break before you resume recording your ideas for another 20 minutes.

The purpose of this session is to brainstorm ideas about how to facilitate and promote collaboration among a team of multidisciplinary members who work on different but related areas of the same project and who do not all share the same office space or building.

Write your ideas on the provided cue-cards. Only record one idea per card. The more ideas you can think of, the better. Do not evaluate your own ideas but record all of them. Try to be as clear and concise as possible. You are encouraged to combine and improve on your ideas as you go.

Do you have any questions?

Instructions for second session

Remember to write down as many ideas as you can. The more ideas you can think of, the better. Do not evaluate your own ideas but record all of them. Try to be as clear and concise as possible. As before, you are encouraged to combine and improve on your ideas as you go.

I-G

Instructions for first session

Welcome to the brainstorming session. The session will consist of two 20-minute brainstorming sessions. In the first session you will brainstorm by yourself. After the first 20 minutes you will be given a brief break before you resume generating new for another 20 minutes with the members of your group.

The purpose of this session is to brainstorm ideas about how to facilitate and promote collaboration among a team of multidisciplinary members who work on different but related areas of the same project and who do not all share the same office space or building.

Write your ideas on the provided cue-cards. Only record one idea per card. Keep your cards to yourself. Do not share your ideas with the other members of your group. The more ideas you can think of, the better. Do not evaluate your own ideas but record all of them. Try to be as clear and concise as possible. You are encouraged to combine and expand on your ideas as you go.

Do you have any questions?

Instructions for second session

During this session, you'll be brainstorming as a group of three. Place all the ideas you came up with in the centre of the table for all to see. Continue recording new ideas on cue-cards (one idea per card) then place the card in the centre of the table and state the idea aloud as you do this. Remember, the purpose of brainstorming is to think of as many ideas as you can, the more ideas the better. Combine, and expand on ideas as you feel is appropriate, recording any new combinations or elaborations on a new cue card. Do not evaluate each other's ideas. Try to be as clear and concise as possible.

Do you have any questions?

G-I

Instructions for first session

Welcome to the brainstorming session. The session will consist of two 20-minute brainstorming sessions. During the first session you will brainstorm in a group of three. After the first 20 minutes you will be given a brief break before you resume recording your ideas for another 20 minutes on your own.

The purpose of this session is to brainstorm ideas about how to facilitate and promote collaboration among a team of multidisciplinary members who work on different but related areas of the same project and who do not all share the same office space or building.

During this session, you'll be brainstorming as a group of three. Write your ideas on the provided cue-cards. Only record one idea per card. When you've finished writing your ideas down place the card in the centre of the table for all to see and state your ideas aloud. The more ideas you can think of, the better. Combine, and expand on ideas as you feel is appropriate, recording any new combinations or elaborations on a new cue card. Do not evaluate each others ideas. Try to be as clear and concise as possible.

Do you have any questions?

Instructions for second session

During this session you will brainstorm individually. You may refer to ideas that were previously generated however you should record new ideas that were not discussed during the group session. You are encouraged to combine and expand any ideas that were discussed in the previous session as well as your own new ideas. Again, only record one idea per cue card. Keep your cards to yourself. Do not share your new ideas with the other members of your group. The more ideas you can think of, the better. Do not evaluate your own ideas but record all of them. Try to be as clear and concise as possible.
Do you have any questions?

Janet Mantler, Chair of the Carleton University Research Ethics Committee for Psychological Research (520-2600, ext. 4173, and Mary Gick Chair of the Department (520-2600, ext. 2648).

APPENDIX G

Feedback

Please provide any comments you have regarding this brainstorming session such as which session you preferred or thought worked better and why. Any information you provide would be very helpful and will be kept strictly confidential.

APPENDIX H

Instructions for Coders

Phase 1

Provided are 18 envelopes each with a set of ideas written on cards that were generated by brainstorming participants. These ideas are exact duplicates of what each participant recorded. Some ideas may appear more than once. Please go through each set of ideas one at a time and group together which ideas if any are repetitions of another. DO NOT mix sets of ideas. Ideas that are combinations of earlier ideas or elaborations on earlier ideas are NEW ideas and are NOT repetitions.

Example of a combination, the idea “social activities” and “use the collaboration process as research data” can give the combination “collect research data from social activities” or “create a social activity surrounding a research task”.

Example of an elaboration, is an idea that closely resembles another but provides additional details or other information such as “presentation” could be elaborated to “have different groups present to everyone on their progress”. Similarly, when an idea is identified as being a more generic version of another idea, the more detailed idea is considered the elaboration of the generic one.

Finally, clip the ideas you have grouped together with the provided clips and return the set to the bag.

APPENDIX I

Instructions for Coders

Phase 2

Provided are 18 envelopes each with a set of ideas written on cards that were generated by brainstorming participants. These ideas are exact duplicates of what a participant recorded. Please go through each set of ideas one at a time and group together which ideas you think are similar and belong together in the same category. DO NOT mix sets of ideas.

For example, the ideas "party", "movie night", "bowling" and "social activities" could all belong to the same category called "social activities", whereas "work-updates" would belong to a separate category.

Once you have finished grouping a set of ideas indicate next to the idea on the card itself, a "1" if you think it is a combination of other ideas or an elaboration on another idea. Mark a "0" if it is neither.

Example of a combination, the idea "social activities" and "use the collaboration process as research data" can give the combination "collect research data from social activities" or "create a social activity surrounding a research task".

Example of an elaboration, is an idea that closely resembles another but provides additional details or other information such as "use the collaboration process as research data" could be elaborated to "have the project recognized as a case study to be developed by a third outside party such as the Harvard Business School". Similarly, when an idea is identified as being a more generic version of another idea, the more detailed idea is considered the elaboration of the generic one.

Finally, when you have done this for each set of ideas please provide a single combined rating from 0 to 100 for each idea on the back of the card. Base your rating on the extent to which the ideas show promise first in being USEFUL and second in being NEW. If an idea is neither useful nor new it should receive the lowest ratings.

APPENDIX J

Mean and SD table for Dependent Variables

Number of Ideas and Categories Across Conditions and Session

	Condition											
	G - I				I - G				I - I			
	Session 1		Session 2		Session 1		Session 2		Session 1		Session 2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
No. Ideas	32.33	6.47	52.83	15.94	33.67	11.96	19.67	11.08	45.83	4.44	30.33	8.02
No. Categories	18.17	3.82	23.89	8.51	15.00	3.87	16.44	4.35	17.94	3.32	20.83	4.81
No. Elaborations	10.12	4.58	16.17	5.40	9.72	4.05	5.11	3.68	15.11	2.24	9.17	1.64
No. Original Ideas	6.50	2.07	14.17	3.87	8.67	3.72	4.83	2.99	13.00	3.35	10.67	5.61
Quality of Ideas	52.54	4.26	60.26	1.79	59.37	4.06	57.42	3.74	60.13	4.35	60.02	2.86
No. Good Ideas	2.79	1.80	6.17	2.94	3.67	2.48	1.50	1.41	5.34	2.68	3.06	2.32

APPENDIX K

Proportion of Participation across Sessions

	Low						Middle						High					
	G - I		I - G		I - I		G - I		I - G		I - I		G - I		I - G		I - I	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All Sessions	.25	.05	.27	.06	.24	.03	.35	.02	.33	.04	.35	.06	.39	.06	.40	.05	.41	.04
Session 1	.24	.06	.25	.04	.25	.03	.34	.03	.32	.04	.32	.03	.42	.06	.43	.06	.43	.04
Session 2	.24	.05	.18	.11	.21	.03	.34	.02	.34	.06	.30	.05	.42	.05	.48	.06	.48	.06

APPENDIX L

MANOVA: No. ideas and no. idea categories

Effect	Source	Wilk's λ	df	F	Sig.
Between	Condition	0.54	4	2.49	.066
Within	Session	0.44	2	8.81	.003
	Session * Condition	0.23	4	7.62	.000

ANOVA: No. ideas and no. idea categories

Source	Measure	SS	df	MS	F	Sig.
Session	Ideas	81.00	1	81.00	1.36	.261
	Category	101.14	1	101.14	17.99	.001
Session * Condition	Ideas	2488.50	2	1244.25	20.96	.000
	Category	28.44	2	14.22	2.53	.113

Interaction: Simple main effect for session

Condition	Wilk's λ	df	F	Sig.
G - I	0.27	2	19.07	.000
I - G	0.58	2	4.99	.023
I - I	0.49	2	7.40	.006

Interaction: Simple main effect for condition

Session	Wilk's λ	df	F	Sig.
One	0.51	4	2.78	.046
Two	0.35	4	4.83	.004

APPENDIX M

F Tables for Elaboration

Elaboration

Tests of Within-Subjects Effects

Source	Wilk's λ	df	F	Sig.
Session	0.82	1	3.22	.093
Session * Condition	0.27	2	20.00	.000

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Condition	225.71	2	112.85	4.94	.023

Interaction: Simple main effect of session

Condition	Wilk's λ	df	F	Sig.
G - I	0.47	1	16.81	.001
I - G	0.60	1	9.93	.007
I - I	0.48	1	16.48	.001

APPENDIX N

F Tables for Originality

Originality

Tests of Within-Subjects Effects

Source	Wilk's λ	df	F	Sig.
Session	0.97	1	0.45	.512
Session * Condition	0.24	2	23.53	.000

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Condition	163.72	2	81.86	3.52	.056

Interaction: Simple main effect of session

Condition	Wilk's λ	df	F	Sig.
G - I	0.30	1	35.38	.000
I - G	0.63	1	8.85	.009
I - I	0.82	1	3.28	.090

APPENDIX O

F Tables for Mean Quality

Quality

Tests of Within-Subjects Effects

Source	Wilk's λ	df	F	Sig.
Session	0.81	1	3.49	.082
Session * Condition	0.47	2	8.60	.003

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Session * Condition	81.12	2	40.56	2.37	.128

Interaction: Simple main effect of session

Condition	Wilk's λ	df	F	Sig.
G - I	0.44	1	19.44	.001
I - G	0.92	1	1.25	.282
I - I	1.00	1	0.00	.954

APPENDIX P

F Tables for Number of Good Ideas

Number of good ideas

Tests of Within-Subjects Effects

Source	Wilk's λ	df	F	Sig.
Session	0.97	1	0.48	.497
Session * Condition	0.36	2	13.60	.000

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Session * Condition	24.95	2	12.48	1.46	.264

Interaction: Simple main effect of session

Condition	Wilk's λ	df	F	Sig.
G - I	0.50	1	14.86	.002
I - G	0.71	1	6.09	.026
I - I	0.69	1	6.73	.020

APPENDIX Q

F Tables for Proportion of Participation

ANOVA: Proportion of participation across sessions

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Ranking	0.19	2	0.10	41.07	.000
Condition	0.00	2	0.00	0.00	1.000
Ranking * Condition	0.01	4	0.00	0.55	.698

Proportion of Participation for Session 1

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Ranking	0.29	2	0.14	68.10	.000
Condition	0.00	2	0.00	0.00	1.000
Ranking * Condition	0.00	4	0.00	0.32	.864

Proportion of Participation for Session 2

Tests of Between-Subjects Effects

Source	SS	df	MS	F	Sig.
Ranking	0.56	2	0.28	78.42	.000
Condition	0.00	2	0.00	0.00	1.000
Ranking * Condition	0.03	4	0.01	2.10	.097

APPENDIX R

Slope and Std Error Table for Rate of Idea Generation

Chow test: Rate of idea generation

Rate of idea generation across sessions

Condition	Slope	Std. error	t	Sig.
G - I	2.15	0.07	31.82	.000
I - G	1.29	0.05	27.76	.000
I - I	1.85	0.04	48.79	.000

Rate of idea generation for session one

Condition	Slope	Std. error	t	Sig.
G - I	1.52	0.08	18.29	.000
I - G	1.72	0.06	27.61	.000
I - I	2.20	0.06	37.69	.000

Rate of idea generation for session two

Condition	Slope	Std. error	t	Sig.
G - I	2.66	0.17	16.01	.000
I - G	1.05	0.10	10.17	.000
I - I	1.49	0.08	18.24	.000