Improving Group Creativity:
Brainstorming Versus Non-brainstorming Techniques in a GSS Environment

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Abstract

Creativity is increasingly important in today's fast changing world. The use of Group Support Systems has been shown to improve the quantity and quality of ideas produced by groups during idea generation. Similarly, creative techniques may be used to increase creativity. Therefore, the use of creative techniques together with a GSS may help groups think more creatively. Brainstorming is the most used and studied of the techniques. However, to further increase creativity, other types of creative techniques may be used.

This paper presents a theory addressing structural aspects of both creative techniques and GSS, including testable hypotheses. A laboratory experiment is described that tests these hypotheses for three creative techniques (Brainstorming, Assumption Reversals and Analogies) implemented using a GSS. Results support the proposed theory. Analogies produced fewer but more creative ideas. Assumption Reversals produced the most ideas, but these ideas were less creative than ideas produced by Analogies and Brainstorming.

1. Introduction

Organizations need to tap the creativity of their members in order to respond to today's turbulent environment. In order to increase the creativity of groups, techniques for improving idea generation are of continuing interest. Idea generation, is critical during general problem solving, new product development, business process improvement; and a host of other applications.

Many organizations are recognizing the importance of teams for problem solving [27, 22] because the necessary information is often distributed among group members and cooperative problem solving by a group may lead to acceptance at the implementation stage. However, getting a group of experts to work together efficiently and effectively can be difficult [16]. Group Support Systems (GSS) can mitigate some of these problems, by providing at least three functions: parallel communications, anonymity, and group memory [41]. Parallel communications can help a group during idea generation by allowing individuals to communicate simultaneously thereby reducing production blocking, whereas anonymity helps reduce evaluation apprehension. Both of these result in more equal participation [41]. Group memory supports creativity by allowing participants to view ideas generated by others and hence facilitates piggybacking of ideas. Indeed, both laboratory experiments [20] and field studies [40] have found that GSS groups can generate ideas of a higher quantity and quality than non-GSS groups. Moreover, GSS can contribute to creativity by overcoming space and time constraints, thus allowing people of diverse background, culture and expertise to participate in idea generation sessions, and groups of a larger size to be accommodated.

Notwithstanding the importance of creative outcomes, humans are sometimes poor idea generators [6]. Although everyone is potentially creative, a variety of blocks may limit the creative process. These blocks can be intellectual, perceptual, emotional, cultural or environmental and can arise either from within the

individual or be due to social and contextual factors [8]. Evidence suggests that certain creative techniques may help overcome some of these blocks [24, 54, 8]. Because creative techniques affect the number and creativity of ideas produced during idea generation, tools and techniques for improving idea generation are of continuing interest to both researchers and practitioners. Of the creative techniques available for idea generation, only Brainstorming has been extensively used and studied [36, 29]. Brainstorming, however, relies on the piggybacking of others' ideas to improve creativity. To increase creativity, the problem boundaries should at least be stretched if not broken. In order to do this, other creative techniques, which use different forms of creative stimuli, may be used.

Since GSS and creative techniques have been shown to aid creativity, creative techniques used in conjunction with a GSS should help people to think more creatively. However, beyond variants of Brainstorming, little research has been done on the use of creative techniques with a GSS. The current laboratory experiment was designed to examine whether it is possible to increase creativity by using other creative techniques with a GSS. To test this, two creative techniques with very different attributes are compared to Brainstorming. The first technique, Analogies, used unrelated stimuli to achieve a perspective shift and force fitting to link the perspective shift back to the problem. The second technique, Assumption Reversals, used related stimuli and free association. Subjects, working in a group, used one of these three methods to generate ideas. The quantity and creativity of ideas were evaluated and compared across the three treatments.

After providing additional background and motivation for the research, the next section culminates in the research hypotheses. Next, the research methods are presented. The results and discussion then follow, and the paper concludes with suggestions for future research.

2. Background

When creative techniques are used in conjunction with a GSS, both of these impose structures on the idea generation process. The effects of these structures are described in this section, and propositions and hypotheses developed.

2.1. Attributes of creative techniques

Mednick [35] has defined the creative thinking process as "the forming of associative elements into new combinations which either meet specified requirements or are in some way useful. The more mutually remote the elements of the new combination, the more creative the process or solution". The key goal of many creative techniques is to achieve a shift in perspective with respect to the problem, which is often achieved by means of some kind of stimulus. *Internal stimuli* include the problem statement itself and the growing pool of ideas that are generated during the process. Methods may also use *external stimuli,* which may include objects, sounds, pictures, or concepts such as analogies. External stimuli may be related or unrelated to the problem. The major phases in this type of creative approach are to change the perspective, establish a link with the problem, and generate ideas. These creative techniques impose a structure on the idea-generation process, and practitioners and researchers have suggested that there is a relationship between these structures and the characteristics of the resulting ideas. The key structures are stimulus relatedness and the method of linking the new perspective back to the problem [37, 53].

Stimulus relatedness may be a determinant of idea creativity. Techniques that use stimuli that are *unrelated* to the problem are more likely to produce novel ideas than techniques that use only *related* stimuli [53]. This may be because unrelated stimuli provide a greater degree of perspective shift with respect to the problem. The greater the perspective shift, the more likely that "remote elements" will be formed into new combinations, and hence produce more creative ideas [35].

The method of linking the new perspective to the problem may be by free association or forced relationships. *Free association* occurs when participants follow a train of thought and rely largely on chance and incubation [53]. Usually the most cognitively available associations are the ones that surface most. If the most cognitively available associations are common relationships, the resulting ideas will also be common rather than creative. In contrast, *forced relationships* is the forcing together of two or more objects, products, or ideas to produce new objects, products, or ideas. With forced relationships, participants may be associating two concepts for the first time, and therefore the chance of forming remote associations and hence producing creative ideas may be greater.

Examples of techniques that use no external stimulus are Brainstorming and Brainwriting. Examples of techniques that use related stimuli and free association are Assumption Reversals and Attribute Listing [53]. Examples of techniques that use unrelated stimuli and forced relationships are Analogies, Object Stimulation [54], and Guided Fantasy [37, 24]. It has been asserted that techniques that use unrelated stimuli and forced relationships are more likely to produce novel ideas than techniques that use related stimuli and free association [53]. This assertion is supported by two studies [24, 32]. However, neither of these studies used a GSS, and virtually no research exists comparing the effects of these types of techniques to Brainstorming when all methods are supported by a GSS. Unrelated stimuli, rather than related stimuli, are likely to lead to a radical perspective

shift which will likely involve 'remote elements'. Forced relationships will force these 'remote elements' together, hence the likelihood of forming remote associations [35] and hence creative ideas will be greater than with free association. This leads to the first proposition:

Proposition1: Techniques that use unrelated stimuli and forced relationships will produce ideas that are more creative than those that use related stimuli and free association.

However, the same structural features of creative techniques that increase the novelty of ideas may lead to a reduction in the quantity of ideas produced. For instance, methods designed to increase the degree of perspective shift and hence the diversity of concepts or "elements" in a person's mind may also increase the cognitive processing required to bring them together. Increased cognitive processing should increase the time required to generate each idea, and therefore reduce the number of ideas generated in a given period of time [39]. This leads to the second proposition:

Proposition 2: Techniques that use unrelated stimuli and forced relationships will produce fewer ideas in a fixed time period than those that use related stimuli and free association.

2.2. Attributes of group support systems

Numerous experiments [18, 20, 44, 9] and field studies [41] have shown that groups using a GSS can generate ideas of a higher quantity and quality than non-GSS groups. The key structures responsible for this difference are anonymity [7], simultaneity [19, 52], and group memory. When implementing different creative techniques with a GSS, the structures of anonymity and simultaneity will be the same but, by necessity, the use of the group memory may be different. This raises a number of questions which will be examined by this study.

The availability of a group memory, provided by the GSS, should encourage the production of creative ideas. Mutual stimulation and piggybacking of ideas is considered important for promoting idea production and is a key ingredient in many idea generation techniques such as Brainstorming. A large pool of ideas may provide a wider variety of stimulation for the generation of additional ideas. The creativity of ideas present in the group memory has been shown to affect the creativity of subsequent ideas [50]. Further, participants may see relationships among diverse ideas and combine them to generate new ones.

Collective memory, as provided in a GSS, is distinctly different from that in manual idea generation processes. Firstly, GSS, through parallel input, allows the group memory to be larger. Secondly, the ability to configure collective memory within GSS makes it possible to manipulate the exposure of each participant to the ideas generated by the other participants in a variety of ways.

One way that this occurs is through the *number of lists or dialogs* used to collect ideas. This decision can have an effect on the quantity and quality of the ideas produced. For example, it has been found that groups using multiple dialogs, generated more ideas than groups using a single dialog [14, 1], with higher quality ideas being produced in the former study. When creative techniques are adapted for use with a GSS, the way group memory is portioned into dialogs may be necessarily different. For example, with traditional electronic brainstorming, N+1 unnamed dialogs are often used, where "N" is the number of participants. However, with methods such as Analogies and Assumption Reversals, the number of dialogs that are used will emerge from the number of assumptions or analogy details generated by participants. To date, no research has investigated how many dialogs will emerge with these creative techniques.

A second way that exposure to the ideas may be manipulated is by the *naming of the dialogs*. Experiments have found that decomposing the problem into separate sub problems, each having its own named dialog, results in the generation of ideas of a higher quantity and quality than those generated when the problem is left intact [15, 10]. This is because problem decomposition expands the problem space by focusing attention over the entire problem. In a similar way, thinking of possible causes of the problem before Brainstorming [46] expands the problem space and leads to the generation of more ideas. When the Assumption Reversals technique is implemented using a GSS, the reversed assumptions will be shown as dialog labels. It is not known whether the intended triggers embodied in the dialog names will produce more ideas than those produced by the smaller number of fixed, unnamed dialogs used with traditional brainstorming. Decomposing the problem into multiple named dialogs, as opposed to leaving the problem intact, results in the generation of more ideas. This leads to the third proposition:

Proposition 3: Methods that decompose the problem into multiple named dialogs will produce more ideas than those that do not.

A third way that exposure to the ideas may be manipulated is by the *movement between the dialogs.* This may be under the control of the participants themselves, the control of the facilitator, or the control of the GSS. To date, no research has investigated this aspect of the group memory. *Free*, as opposed to *forced*, movement between dialogs may result in cognitive inertia. Cognitive inertia occurs when an uninterrupted thought process follows a train of thought that remains within a paradigm or subject area. Individuals might follow a train of thought as far as it goes, using it as a basis for generating ideas, before attending to the ideas generated by other participants in different dialogs. It is possible that people will not actively use multiple dialogs. Even if several dialogs were available, group members might choose to focus on only

one or two dialogs and ignore others because this is cognitively simpler [14]. Cognitive inertia results in clusters of homogeneous ideas, since an uninterrupted stream of ideas will tend to follow a consistent train of thought in a set of semantically similar subcategories, because related stimuli activate related production rules [15]. Thus, cognitive inertia results in clusters of homogeneous ideas which in turn results in ideas of lower creativity. This leads to the fourth proposition:

Proposition 4: Methods that use forced movement between dialogs will produce ideas that are more creative than those that use free movement.

2.3. The creative techniques used in this study and their implementation

Three creative techniques were used in this study: Brainstorming, a technique that uses no external stimulus; Assumption Reversals, a technique that uses related stimuli and free association; and Analogies, a technique that uses unrelated stimuli and forced relationships. GroupSystems for Windows by Ventana Corporation was the software used to implement the techniques. Selection of the specific tools within GroupSystems was based upon how well they supported each creative technique. The techniques and their implementation is described below:

2.3.1. Brainstorming. Classical Brainstorming was devised in the late 1930s by advertising executive Alex F. Osborn. There are two core principles: deferred judgment, and quantity breeds quality. There are four rules based on these principles [42]:

First, criticism is ruled out during ideation because early evaluation may impede the creative process. Second, unconventional ideas are welcomed. Often the most desirable ideas are those which may at first seem wild and far out. Third, quantity is wanted. The more ideas generated, the greater the chance a successful solution will be found. And fourth, combination and improvement are sought. The purpose of this rule is to encourage the generation of additional, better ideas by building on the ideas of others. This activity is commonly referred to as "hitchhiking" or "piggybacking."

Of the creative techniques available for idea generation, Brainstorming is by far the most used by practitioners [21] and the most studied by researchers. Brainstorming or some variant has been used in a substantial proportion of idea generation research studies, both in a GSS environment [11, 33, 12, 45, 34] and in a manual environment [36, 29]. Brainstorming was therefore used as a baseline with which to compare the effects of the other two techniques in this study. Phases of the Brainstorming idea generation technique are:

1. Read the problem.
2. Generate ideas by free association.
3. Continue to generate ideas by free association, using the problem as well as other ideas generated as stimuli.

With this method, free association is the principal structure for both changing one's perspective as well as generating ideas. Because there is no external stimulus, there is no structure or procedure in Brainstorming to deliberately achieve a perspective change, as in Assumption Reversals and Analogies. Brainstorming relies on chance to achieve the perspective shift. The problem statement serves as an initial stimulus for generating a modest perspective shift as well as a stimulus for generating ideas. As idea generation gets under way, the growing pool of ideas, both one's own and those contributed by others, become the principal means of stimulating new ideas.

The Electronic Brainstorming (EBS) tool was used to implement the Brainstorming treatment. With this tool, a group of N people, each at their own computer terminal, exchange ideas typed on N+1 unnamed idea collection dialogs. At any one time, a participant is only able to see the ideas in one dialog, but is able to move to another dialog at will, with or without entering an idea. With this tool, the multiple dialogs are automatically rotated among participants as ideas are submitted.

2.3.2. Assumption Reversals. Assumption Reversals has been used by practitioners both manually [23, 54, 48] and with a GSS [13]. However, this technique has not been studied in relation to other creative techniques in controlled laboratory experiments. Phases of the Assumption Reversal idea generation technique are:

1. List all the major assumptions about the problem.
2. Reverse each assumption in any way possible.
3. Using the reversals as stimuli, generate ideas.

The procedure of listing assumptions and then reversing them is the external stimulus, which is the means of changing perspective. This invokes a moderate perspective change. These reversed assumptions, however, are still related to the problem. The link back to the problem and subsequent idea generation is by free association.

The Categorizer tool was used to implement the Assumption Reversal treatment because it supports named idea collection topics. Participants list major assumptions about the problem as list items in the tool. The technographer then, with input from participants, reverses the assumptions. Participants then submit ideas to solve the problem as comments behind the reversed assumptions. Participants are able to move freely among the reversed assumptions. Unlike the EBS tool used in the Brainstorming treatment, the Categorizer tool does not automatically rotate dialogs upon idea submission. Rather, participants can choose to move at will among the various dialogs.

2.3.3. Analogies. An analogy is a statement about how objects, persons, situations, or actions are similar in process or relationship to one another. Many authors have emphasized the importance of analogy in creativity [4, 28]. Analogies have been used successfully by numerous practitioners, both as a stand-alone technique and as a part of formal techniques, such as Synectics [47, 53]. There have been a few studies of analogies [5, 17, 43], although these have all operationalized the technique in different ways. Although it has been suggested that Synectics be adapted for use with a GSS [51], there have, as yet, been no studies of analogies with a GSS. Phases of the Analogies idea generation technique are:

1. Decide the major principle represented by the problem.
2. Use the major principle to generate a list of analogies that are similar in concept.
3. Select any of the analogies that look interesting and describe each in detail. Elaborate on the analogy by listing details such as parts, functions or uses. While completing this step, try to forget about the problem.
4. Force fit the analogy descriptions back to the original problem in order to suggest ideas for solving the problem.

The process of generating analogies and then elaborating on the details creates the external stimulus. The change in perspective is achieved first by generating analogies, which are still related to the problem, and then describing the analogies in detail, which is unrelated to the problem. This should achieve a radical perspective shift. Force-fitting the analogy details back to the problem is intended to associate unrelated elements.

The Categorizer tool was also used to implement the Analogies treatments because it supports named idea collection topics and the multiple levels of hierarchy required. First, Categorizer allows analogies to be listed as list items. The technographer then moves the analogies into category buckets. Participants choose any of the analogies and list short descriptions or details about the analogy, as list items in the Categorizer tool, while forgetting about the initial problem. Participants then use the details as stimuli to suggest ideas for solving the problem, which are entered as comments behind the detail. Participants are allowed to move freely among the dialogs.

2.4. Hypotheses

2.4.1. Quantity. From Proposition 2: Techniques that use unrelated stimuli and forced relationships will produce fewer ideas in a fixed time period than those that use related stimuli and free association. Therefore it follows that Analogies, which uses unrelated stimuli and forced relationships, will produce fewer ideas in a fixed time period, than both Brainstorming and Assumption Reversals, which use related stimuli and free association.

From Proposition 3: Methods that decompose the problem into multiple named dialogs will produce more ideas than those that do not. In Brainstorming all the ideas generated are placed in seven lists or 'dialogs'. In Assumption Reversals each reversed assumption has a list of ideas, or 'dialog', associated with it. Similarly, in Analogies each analogy detail has a 'dialog' associated with it. Therefore it follows that both Assumption Reversals and Analogies will produce a large number of named dialogs which will in turn produce a larger number of ideas than Brainstorming which uses a smaller number of unnamed dialogs.

Therefore Assumption Reversals will produce more ideas than both Brainstorming and Analogies.

Regarding the comparison of Analogies with Brainstorming, we don't know which will be stronger: the larger cognitive load of Analogies (resulting in a smaller number of ideas than Brainstorming) or the problem expanding effects of named multiple dialogs (resulting in a larger number of ideas than Brainstorming). However, although the GSS structures are similar for Assumption Reversals and Analogies, the names on the dialogs for Analogies are unrelated to the problem (being analogy details) and so are unlikely to expand the problem space in the same way. Therefore:

H1a: Participants using the Assumption Reversals technique will generate more ideas in a fixed time period than participants using the Brainstorming technique.

H1b: Participants using the Brainstorming technique will generate more ideas in a fixed time period than participants using the Analogies technique.

2.4.2. Creativity. From Proposition1: Techniques that use unrelated stimuli and forced relationships will produce ideas that are more creative than those that use related stimuli and free association. Therefore it follows that Analogies, which uses unrelated stimuli and forced relationships, will produce ideas that are more creative than both Brainstorming and Assumption Reversals, which use related stimuli and free association.

From Proposition 4: Methods that use forced movement between dialogs will produce ideas that are more creative than those that use free movement. Therefore it follows that Brainstorming which uses forced movement between dialogs will produce ideas that are more creative than both Assumption Reversals and Analogies which use free movement.

Therefore Assumption Reversals will produce the least creative ideas.

Regarding the comparison between Brainstorming and Analogies, we don't know which will be the stronger: the use of unrelated stimuli and forced relationships for Analogies (resulting in ideas that are more creative than those produced by Brainstorming) or the effect of forced

movement between dialogs for Brainstorming (resulting in ideas that are more creative than those produced by Analogies). However, the forced movement for Brainstorming will still only expose participants to related ideas, whereas the technique effects of Analogies will expose them to unrelated ideas. Therefore:

H2a: The ideas generated by participants using the Analogies technique will more creative than ideas generated by participants using the Brainstorming technique.

H2b: The ideas generated by participants using the Brainstorming technique will be more creative than ideas generated by participants using the Assumption Reversals technique.

3. Methodology

3.1. Research design

In order to test the hypotheses, a 3 x 1 single-factor experimental design was used. The design included Creative Technique as the independent variable, and two factors (Quantity and Creativity of ideas) as dependent variables. There were twenty-seven groups in all, nine groups in each treatment, and five participants in each group. Participants were randomly assigned to groups, and groups were randomly assigned to different treatments. The same GSS classroom was used for all sessions. In order to control for facilitator effects, the treatments and subject instructions carefully followed a pre-defined script. Treatments were administered to groups but the unit of analysis for this study was the individual.

One hundred and thirty five undergraduate students enrolled in an introduction to business-computer-systems class at a large United States University participated in the experiment. A pre-session questionnaire was given to each of the participants in order to determine that there was no systematic variation in the attributes of participants across treatments. Since individuals vary in their ability to generate ideas [31, 55], and this may confound results in idea generation experiments, it was necessary to prevent systematic bias of ideational fluency ability for participants within treatment groups. A Productive Thinking Test (PTT) [25]was used to measure ideational fluency, and determined that there were no differences across the treatment conditions.

Participants were asked to provide creative ideas for the following problem. "A restaurant located next to campus is losing customers. What can the restaurant do to retain its customers?"

To support analysis of production by each participant, and yet retain a measure of anonymity, a unique Participant Identification Number (PIN) was randomly assigned to each participant. This PIN was entered into GroupSystems by each participant prior to idea generation and was also entered on their questionnaires. This allowed ideas to be tracked to the contributor without making the contributor's name visible to other participants.

3.2. Operationalization of dependent variables

3.2.1. Quantity of ideas. The quantity of ideas was identified by counting the number of ideas generated by each participant. This was obtained from the computer transcripts. Ideas generated by participants were identifiable by the subjects' PIN. Non-ideas, including extraneous comments and incompletely expressed thoughts were excluded. If a participant produced one statement containing a list of ideas, this was disaggregated and the ideas counted individually.

3.2.2. Creativity of ideas. An evaluation scheme for measuring creativity was developed from the creativity literature. In the past, methods of evaluating the creativity of ideas have often been based solely on their ***level*** of creativity. However, some authors [38, 24] argue that creativity level by itself is an inadequate means of characterizing idea creativity, and advocate evaluating creative ideas according to both creativity level and creativity style. In this sense, creativity level corresponds to the *novelty* of the idea, while creativity style corresponds to *paradigm relatedness*, which represents the degree to which an idea relates to the currently prevailing paradigm. Several other authors have deconstructed the dimension of novelty into various sub-dimensions in a similar way. For example, original and transformational [3]; unusualness and transformation power [26]; original, germinal and startling [2]. The sub-dimensions of transformational and germinal seem related to the concept of *paradigm relatedness.* Idea creativity was therefore decomposed into the following sub-dimensions:

- Originality: An idea is most original if no one has expressed it before.
- Paradigm relatedness: The degree to which an idea preserves or modifies a paradigm.

In order to determine the creativity of ideas, each idea was scored independently by two raters using Likert scales on the two sub-dimensions. Scoring definitions were initially developed from the literature and then refined during a training process: two raters scored a sample of ideas on each of the sub-dimensions; correlations were obtained using Pearson's correlation coefficient; differences were discussed, and the definitions refined for each sub-dimension; the sub-dimension scores were derived by taking an average of the two raters' scores; scores for creativity were calculated by aggregating the sub-dimensions and standardized on a scale of 1-7. The process was repeated until the inter-rater reliability was sufficient, that is, > 0.7. Total creativity scores for each participant were

calculated by summing the creativity scores for each idea generated by that person. Average creativity scores for each participant were calculated by dividing the total creativity score by the number of ideas generated by that person. Since total creativity is correlated with quantity, and quantity itself was a dependent variable, average creativity, described as a "purer" measure [29], was used as the creativity measure.

4. Results

Neither of the dependent variables, Quantity and Creativity, were normally distributed. Therefore, the Kruskal-Wallis test was first used. Where this test indicated significant differences between the treatments, the Mann-Whitney test was used to test hypotheses H1a, H1b, H2a, and H2b.

The following table presents the results of the across-treatment comparisons.

Table 1. Comparison of main effects across treatments

	B	R	A	
Quantity				
Mean SD Range	15.47 5.57 6-27	18.60 8.18 9-39	12.71 4.64 2-23	
Kruskal-Wallis	69.29	81.63	53.08	Chi-Square = 12.119 P = 0.002*
Mann-Whitney	41.07	49.93		P = 0.107
Mann-Whitney	51.22		39.78	P = 0.037*
Mann-Whitney		54.70	36.30	P = 0.001*
Creativity				
Mean SD Range	3.28 0.46 2.33-4.38	3.16 0.77 1.95-5.77	3.41 0.44 2.63-4.5	
Kruskal-Wallis	69.77	53.80	80.43	Chi-Square = 10.575 P = 0.005*
Mann-Whitney	51.29	39.71		P = 0.036*
Mann-Whitney	41.48		49.52	P = 0.144
Mann-Whitney		37.09	53.91	P = 0.002*

B = Brainstorming, R = Assumption Reversals, A = Analogies
* = Significant at the 0.05 level.

The results of the tests of the hypotheses are summarized below.

Table 2. Summary of tests of the hypotheses

Dependent Variable	Hypothesis	P	Supported
Quantity	H1a. R>B	0.107	Partially
Quantity	H1b. B>A	0.037*	Yes
Creativity	H2a. A>B	0.144	Partially
Creativity	H2b. B>R	0.036*	Yes

* = Significant at the 0.05 level.

4.1. Quantity of ideas

Assumption Reversals produced 837 ideas, Brainstorming produced 696 ideas, and Analogies produced 572 ideas, making a total of 2,105 ideas. There was a significant difference between the three treatments.

There was no significant difference between Assumption Reversals and Brainstorming at the 0.05 level. However Assumption Reversals did produced more ideas than Brainstorming, and this was almost significant at the 0.1 level. Thus H1a, which stated that Assumption Reversals would produce more ideas than Brainstorming, was partially supported.

Both Assumption Reversals and Brainstorming produced significantly more ideas than Analogies. Thus H1b, which stated that Brainstorming would produce more ideas than Analogies, was supported.

4.2. Creativity of ideas

There was no significant difference in the creativity of the ideas produced by Analogies and Brainstorming at the 0.05 level. However the ideas produced by Analogies were more creative and this was almost significant at the 0.1 level. Thus H1a, which stated that Analogies would produce ideas that were more creative than those produced by Brainstorming, was partially supported.

Both Analogies and Brainstorming produced ideas that were significantly more creative than those produced by Assumption Reversals. Thus H1b, which stated that Brainstorming would produce ideas that were more creative than those produced by Assumption Reversals, was supported.

5. Discussion

5.1. Quantity of ideas

As expected, participants using Analogies generated significantly fewer ideas than those using Assumption Reversals and Brainstorming. It was hypothesized that this was due to the higher cognitive load experienced by participants using this technique. Perceived Ease of Use was also measured in this study. Perceived Ease of Use may be related to the amount of cognitive effort involved. That is, the more effort required, the harder the technique is perceived to be. Perceived Ease of Use was measured using an adaptation of an instrument used in prior

research [49]. Analogies was perceived to be significantly harder to use than Brainstorming ($p = 0.002$), and participants found Assumption Reversals and Brainstorming equally easy to use ($p = 0.209$). This confirms the difficulty experienced with Analogies and supports the theory. The technique of Analogies uses analogies and analogy details as the external stimulus which is unrelated to the problem. The resulting radical perspective shift results in a high diversity of elements. The force fitting of these remote elements results in a high cognitive load. This considerable cognitive load reduces the number of ideas produced. The techniques of Assumption Reversals and Brainstorming both had a lower cognitive load resulting in more ideas being produced.

Assumption Reversals produced more ideas than Brainstorming, but only at the 0.1 level. Thus the effect of the reversed assumptions in expanding the problem space, and allowing the production of more ideas, was slight.

5.2. Creativity of ideas

As expected, Assumption Reversals produced ideas which were significantly less creative than those produced by both Brainstorming and Analogies. It was hypothesized that this was caused by the structure of the technique, namely related stimuli and free association, and the movement between the dialogs. In this study, Brainstorming participants, using EBS, were presented with one of the seven dialogs in turn, although they were not required to enter an idea each time. However, Assumption Reversals and Analogies group members, using Categorizer, could *choose* in which dialogs to participate, reading ideas from and writing ideas into different dialogs at will. Participants' discretion regarding whether to move among dialogs may have resulted in a tendency to remain within a dialog and therefore resulted in cognitive inertia. Cognitive inertia results in clusters of homogeneous ideas, or elements of low diversity, which in turn result in ideas of lower creativity. To establish whether participants in the Assumption Reversals treatment had suffered from cognitive inertia, an analysis of the distribution of each participant's ideas among the dialogs was conducted. Clusters of four or more ideas produced by the same participant in one dialog were counted. The Assumption Reversals treatment produced nineteen clusters, including one of twenty-three ideas. Conversely, only nine clusters were produced by the Analogies treatment. This difference cannot be completely explained by the difference in number of ideas produced. It is possible that cognitive inertia did not occur with the Analogies treatment because the effect of the technique was stronger than the effect of the GSS.

Table 3. Distribution of ideas

Method	Av. no. dialogues	No. of clusters
Brainstorming	7	N/A (forced movement)
Assumption Reversals	24	19
Analogies	35	9

Analogies produced more creative ideas than Brainstorming, although not significant at the 0.05 level ($p = 0.144$). This was hypothesized to be due to the structure of the creative technique, namely the use of unrelated stimuli and forced relationships. However, it appears that there was a slight effect due to the forced movement between dialogs for the Brainstorming technique.

5.3. Future Research

Creative methods and how they are implemented using a GSS have implications for both idea quantity and creativity. Future research can continue to examine these effects. There were a number of limitations of this study. The methodology adopted was a laboratory experiment, which is subject to a set of well-known limitations, including the use of students and ad hoc groups. Facilitation was a controlled variable in this study and was therefore consistent and passive. In an organizational setting, facilitation would be more active and adaptive. Before this study, there has been no research on the use of creative techniques, other than Brainstorming, with a GSS. Numerous other techniques have been detailed in the literature [53, 8], many of which are designed to further increase creativity by the use of structures which deliberately allow a perspective change, but very few have been subject to controlled investigation. Future work should continue to examine the effects of structural aspects of other creative techniques to provide further generalization of how these structures affect the number and creativity of ideas both with and without a GSS. Future research should also investigate the use of the group memory of the GSS as a separate issue. Variables to be studied include forced versus free movement between dialogues, the number of dialogues produced, and whether the dialogues are named or unnamed. This research may also produce insights into features that can be implemented in future GSS to enhance their ability to support the creative process.

6. Conclusion

This paper has provided both conceptual and practical insights into the use of creative methods with GSS by examining how structural aspects of creative methods and the GSS affect idea quantity and creativity. The considerable potential of GSS to support the creative

process can best be harnessed as research continues to clarify how structural aspects of creative techniques impact key creative outcomes.

7. References

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