The Cognitive Network Model of Creativity: a New Causal Model of Creativity and a New Brainstorming Technique

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Abstract

Creativity is a vital component of problem solving, yet despite decades of creativity research, many of the techniques for increasing creative production still lack compelling theoretical and causal foundations. This paper defines a Cognitive Network Model, a causal model of creative solution generation for problem solving domains. This model is grounded in mechanisms of human cognition which are hypothesized to exist within all individuals, regardless of their intelligence level, socio-economic status, or other variable, personal attributes. Guided by the model, we outline a new Group Support System (GSS) based technique called directed brainstorming. We propose the Cognitive Network Model is useful for explaining the effectiveness of existing creativity techniques, and may represent a basis from which new techniques and technologies for enhancing the creative output of problem-solvers can be developed.

1. Introduction

Creativity is the heart of the quest for a sustainable competitive advantage and organizational survival. Without creativity an organization cannot innovate to improve its performance nor can it survive significant environmental change. In a dynamic, competitive environment it may not be sufficient for an organization to innovate only once; it may need to innovate continuously. Yet, contrary to the obvious importance of creativity, a rich literature suggests that people facing large, complex problems tend to think within a bounded, familiar, and narrow subset of the solution space rather than thinking creatively [7, 33, 48]. In complex problem solving, subjects can overlook as much as 80% of the potential solution space and even be unaware that they are doing so [22]. MacCrimmom & Wagner [29] demonstrate that people are better able to select a specific action from some set of solutions provided to them than they are of actually developing creative solutions to a particular problem area on their own. These findings begin to illustrate a basic limitation of our individual cognitive abilities which conflicts with our need to think creatively. This raises the practical question of “how can we overcome these limitations?”

There are a variety of techniques that may enhance creativity by pushing people to think outside their familiar boundaries to find more unexpected and effective solutions [31, 10, 50], but these techniques seldom derive from a theoretical model. Similarly, a great deal of work has been published showing that Group Support Systems can be used to improve solution generation by teams [14, 13, 15, 37, 49, 21, 9]. But *why* are people better able to produce more creative solutions when they use this technology? Why do these techniques work?

Many authors have offered descriptive models, prescriptive models, and frameworks that address links between creativity and a wide variety of personal characteristics such as personality, eminence, biographical inventories, and intelligence [24, 26, 46, 51, 11, 16, 20, 45, 5, 25]. Theories of this type are generally referred to as Divergent-Thinking Theories. A causal model that frames creativity as a bundle of such personal characteristics could rapidly grow so unwieldy as it incorporates a myriad of personal and experiential factors that it would become too complex to sustain scientific investigation because no study could possibly control all the factors involved. Furthermore, these types of investigations typically seek to describe *the circumstances under which creativity is most likely to occur*, but do not address specific *mechanisms of creativity*, nor how those mechanisms can be used to influence creativity. Such a model could be useful to explain existing creativity techniques, and could provide a foundation for developing new techniques and technologies for enhancing the creative output of problem-solvers. Section 2 of this paper presents a new focus for creative investigation, Section 3 outlines the Cognitive Network Model of Creativity, and Section 4 introduces the technique of directed brainstorming and the application of our model to creative solution generation.

2. Refocusing Creative Investigation

One could define creativity as a property of people. Some people are more creative than others are. However, with this kind of definition, the only prescription for improving creativity would be to find new people. This leaves unanswered the question of how to enhance the creativity of the people already working on the problem. It may be more useful, therefore, to define creativity as a property of solutions themselves, and to ask, *What causes a creative thought to form instead of an uncreative one?*

The framing of creativity as a property of solutions rather than of people is referred to as a judgment-of-products approach [6, 4]. Under this framing, a solution is defined as creative to the extent that it is effective [1, 19, 33], and that it is unique [17, 32, 33]. Reframing that definition in terms of problem-solving invites exploration into the *mechanisms* of creative thought.

We have formalized those insights into the Cognitive Network Model of Creativity (Figure 1), the first model which separates a cognitive mechanism of creative solution generation from individual personality attributes. The following section describes the foundations of this model.

3. A Cognitive Network Model of Creativity

Existence of Perceptual Frames. Our model begins by recognizing that human memory is organized into bundles of related items that derive from our experiences. These individual experiences are grouped together according to different principles such as the time sequence of events (as in episodic memory) [47], the meaning of the perceived items (as in semantic memory) [47], or the similarity or typicality of the items [42, 52]. For the purposes of this model, we refer to these bundles as frames, and assume that the frame, rather than the discrete items within each frame, is the basic unit of knowledge that we store and manipulate in our memory.

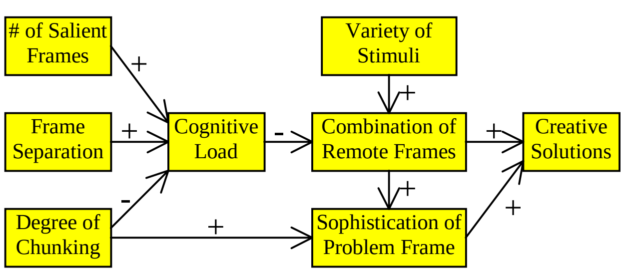

Figure 1. Causal Relationships posited by the Cognitive Network Model of Creativity.

Networks of Frames. Over time, relationships form between individual frames. These relationships, or links, interconnect frames and result in vast networks which represent our knowledge and experiences [8, 27, 29]. Due to the sheer size of these networks it is only possible to actively manipulate a very small number of frames at any one given time. This manipulation occurs in our short term memory, which may be thought of as the workspace for information which is under active consideration at the moment [18]. We refer to individual frames that currently occupy short-term memory as being *salient*, and *activation* as the process that causes some particular frame to become salient. By traversing the links which connect some activated frame to other frames within our knowledge networks, activation of successive frames spreads through our memory causing the activation of yet other frames [7]. When two or more frames are simultaneously salient they are said to be *associated.*

As a result of this association process, three people might perceive the very same tree, but differences in activation patterns may cause them to subsequently frame it quite differently. Framing it as a *plant* could automatically activate leaves, branch, water, and living things. The *shade* frame might automatically lead to rest, heat, parasol, and awning. The *lumber* frame might similarly activate house, lumber mill, and table (Figure 2). Thus, activation of one frame causes activation to spread to other frames which are linked to that concept. This raises the question of how can we lead thinkers to new or different patterns of activation?

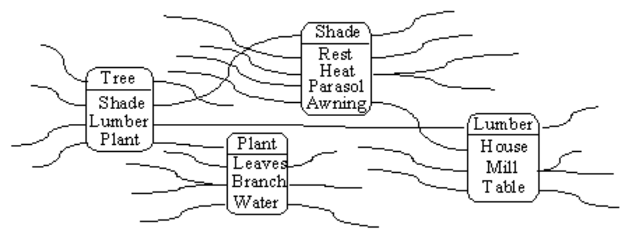

Figure 2. Part of a Knowledge Network

Patterns of activation among frames have been shown to involve two components. The first is an *automatic spreading activation* which occurs without intention or conscious awareness [39, 36], and is relatively independent of the context in which a stimulus appears [2]. This provides a preliminary insight to some of the limitations of problem solving found by Gettys et. al [22]. If a particular stimulus automatically and consistently activates the same sequence of frames on all occasions, this perhaps begins to suggest why problem solvers often fail to consider large areas of the solution space and think primarily within bounded and familiar areas of their knowledge networks [33].

The second type of activation pattern among frames has been shown to be a *conscious, limited capacity spreading activation* that depends upon the context of the stimulus [2] and requires intention and conscious awareness [39, 36]. This seems to suggest that under the proper circumstances, people need not necessarily be bound to the same familiar areas of their knowledge networks when thinking of solutions to problems. For example, how can we make the person who perceives a tree and activates the shade frame activate the lumber frame instead? Perhaps an intervention given to problem solvers that provides a variety of stimuli from different contexts may lead to the exploration of new or different areas of our knowledge networks.

Unexpected Combination of Frames and Creativity. Many researchers assert that the process of making new and unexpected associations between previously unrelated frames often leads to the formation of highly creative solutions while solving problems [17, 30, 33, 41]. Indeed, this is the primary foundation of our Cognitive Network Model of Creativity, which indicates that the creativity of a solution is a function of the degree to which frames that were previously distant from one another become saliently associated in the context of problem-solving.

Cognitive Load and Short-term Memory. This process of combining remote frames is subject to several qualifications. Researchers in psychology generally acknowledge the concept of a cognitive processing resource with fixed capacity which can be simultaneously deployed across multiple tasks such that an increase in the use of resources used by one task (such as activating frames) produces a corresponding decrease in the resources available for the other task (such as manipulating and evaluating those activated frames) [28]. In related work, Miller [35] successfully demonstrated that humans are capable of simultaneously maintaining only a very limited 7 plus or minus 2 "items" in short-term memory. Each of these items is referred to as a *chunk* of information and can range in content from a single letter to multiple frames [3]. Therefore, the more resources that are consumed by holding activated frames or chunks in memory, less resources remain available for processing tasks such as evaluating different combinations of those salient frames. As we attempt to perform both types of tasks simultaneously, cognitive load escalates rapidly and subsequently reduces our creative output.

Factors which Increase Cognitive Load. Due to the potentially large number of intermediate frames which exist between certain frames in our knowledge networks, it may take a great deal of effort to bring concepts that are distant from our salient frame to mind [18]. As we try to push beyond our capacity limit, available resources become consumed and we are forced to "drop" salient items in order to make room for new items in short term memory. This process of venturing into more distant areas in our networks may require the thinker to displace the contents of short term memory many times, requiring increased effort and resulting in greater cognitive loads. Our short term memory thus provides a very narrow window through which to view or access our vast networks of knowledge.

Accordingly, frequent and regular activation patterns of frames coupled with the limits of short term memory form barriers which may help explain why people rarely venture beyond highly familiar concepts while generating creative solutions to problems. This suggests that external stimuli provided to problem solvers may act as fresh entry points into one's cognitive network, possibly reducing the narrow solution framing found by Gettys et. al [22].

Factors which Decrease Cognitive Load. Since chunks can vary in size and complexity [3], one way that we may use short-term memory more efficiently is by creating larger, more complex chunks. This process, known as *chunking*, occurs when several frames that are simultaneously and repeatedly salient become coded into a new, more abstract chunk that contains a more rich set of information (see Figure 2 as 1 chunk containing 4 frames). By combining frames we are able to allow more resources in short term memory for additional chunks. In this respect, chunking can help to offset the extreme capacity limitation of short-term memory by increasing the amount of information contained in each chunk. This suggests that an intervention during the problem solving process that limits the number of frames a person tries to manipulate at any given time or which directs subjects to use knowledge which is chunked into more abstract frames should help to reduce cognitive load. This reduction in cognitive load can lead to more available resources for processing the contents of short term memory, and ultimately, to more creative solutions.

Sophistication of the Problem Frame. The problem people seek to solve will be represented in their minds as one or more frames. If people represent the problem in multiple simple frames, the cognitive load associated with solving the problem may be high. They may either adopt an oversimplified framing of the problem to free up sufficient resources to start thinking about solutions, or they may work to chunk the problem into a single, more sophisticated frame. If people stay with a collection of fragmentary frames to represent the problem, cognitive load may be high enough to limit creativity. If people adopt an over-simplified understanding of the problem and its root causes, they may never activate parts of their cognitive network with task-relevant knowledge, or if they do, they may not recognize it as task relevant, and may therefore discard it. If they work to chunk the problem into a sophisticated frame, that frame may provide links to many task-relevant parts of the knowledge network, which may enhance creativity. Thus, creativity in problem solving may be a function of the degree of sophistication of the problem frame (Figure 1).

From our discussion thus far, it seems less surprising that when cognitive load is high people may not even be aware that they are ignoring major dimensions of the solution space. It is also now easy to see how a decision-maker might repeatedly choose similar courses of action even when facing problems with new parameters. As our already complex environments change, it becomes increasingly necessary to break out of our conventional thought patterns to find creative solutions to problems. The following section presents one such method of increasing the creativity of solutions.

4. Cognitive Network Model and a Directed Brainstorming Experiment

We propose the Cognitive Network Model may be useful for guiding investigations and interventions with respect to creativity. We sought to test its efficacy with an experiment addressing team solution generation supported by a group support system (GSS). If cognitive networks of knowledge form in response to stimuli, then because no two individuals have the same experiences, cognitive networks should be different for every individual, providing a strong case for group collaboration when solving complex problems, particularly during idea generation phases [38, 40]

In most of the 100+ published electronic brainstorming experiments, participants are presented with a single problem stimulus, and subsequently asked to generate as many solutions as they can in the available time. Dennis et al. [12, 13] are notable exceptions. They found that GSS users produced 60% more unique solutions when they were offered three "electronic pages", each bearing a sub-problem (what shall we do about water pollution?; what shall we do about air pollution?; what shall we do about ground pollution?), than when they were prompted to respond to all three sub-problems simultaneously (what shall we do about air, water, and ground pollution?). Like Guilford [23] and Couger [10], Dennis et al. found that decomposing the problem led to more creativity. It may be that each electronic prompt offered a new opportunity to "*reset*" the initial framing of the problem. From any starting place a person may only be able to traverse a finite number or a familiar set of links because each traversal increases cognitive load. Starting at a new frame may "reset" short-term memory and allow a thinker to "jump" to and explore a different section of the cognitive network.

The Cognitive Network Model suggests an intervention that might lead GSS participants to generate more effective and unique solutions by decomposing the solution space to the problem at hand. It is often the case that the criteria for judging the effectiveness of proposed solutions can be determined before solutions are generated. Consider, for example, a team of military planners who need to generate possible courses of action in response to an enemy threat. Before the planners begin, they know from past experience the best solutions are those that are fastest, most surprising, most destructive to the enemy, and that cause the fewest casualties. We reasoned that during brainstorming we could present problem-solvers with a series of stimuli derived from the criteria for an effective solution. For example,

- "Give me a solution that we can implement quickly."
- "Now give me a solution that will catch the enemy by surprise."
- "Now give me a solution that will be highly destructive to the enemy."
- "Think of a solution that will reduce the number of casualties."

And so on. In this manner, we can lead problem solvers through a structured brainstorming session which directs the attention of the participants to different facets of the solution space. We call this method *directed brainstorming*. The Cognitive Network Model suggests that directed brainstorming should have at least two positive effects on creativity. First, it continuously moves the problem-solvers to new starting categories, which should allow them to more easily access discontiguous nodes of their cognitive networks. Second, it specifically moves them into areas of their cognitive networks where new and unique solutions may be found by helping them avoid the bounded, familiar, and narrow activation patterns that often occur during problem solving activities. We therefore hypothesized:

H1: Groups engaged in directed electronic brainstorming will produce a higher number of unique solutions than groups engaged in non-directed electronic brainstorming.

H2: Groups using directed electronic brainstorming will produce a higher concentration of unique solutions than will groups using a non-directed electronic brainstorming method.

H3: Groups using directed electronic brainstorming will produce more effective solutions than will groups using a non-directed electronic brainstorming method.

However, there exists another set of hypotheses which compete with those derived from directed brainstorming. While discussing the results of Dennis et. al [12], we suggested that each prompt given to the participants offered a new opportunity to "*reset*" the initial framing of the problem, thus leading to greater creativity. It is therefore possible that any benefit experienced in the directed brainstorming treatment would similarly result from merely interrupting the cognitive process of each group member while generating solutions.

The rationale is that when individuals are engaged in a problem solving task, their cognitive resources can be quickly consumed by their efforts, contributing to narrow spreading activation patterns and exploration of narrow subsets of the actual problem solution spaces. Informally termed *cognitive resonance*, this phenomenon proposes individuals become stuck or “resonate” in a particular pattern of thought and are unable to break free. Accordingly, *any interruption* or stimulus provided to an individual who is experiencing cognitive resonance should help by “wiping the slate clean” and providing a new entry-way into the cognitive network from which the problem solver may then proceed. Thus, it is possible that the interruption created by each directed brainstorming prompt, rather than the solution space relevant content of that prompt, can provide the greater benefit to the groups. We therefore hypothesized:

H4: Groups engaged in interrupted electronic brainstorming will produce the same number of unique solutions as groups engaged in directed electronic brainstorming.
H5: Groups engaged in interrupted electronic brainstorming will produce the same concentration of unique solutions as groups using a directed electronic brainstorming method.
H6: Groups engaged in interrupted electronic brainstorming will produce the same number of effective solutions as groups using a directed electronic brainstorming method.

5. Experiment

5.1 Participants and Task

Eighty six students from a large university were randomly assigned to 4 or 5 person groups and participated in non-directed, directed, and interrupted electronic brainstorming sessions. All subjects were asked to generate solutions to a set of complex, interrelated symptoms in an imaginary school of business task that is a moderate-ambiguity variation [44] of the hidden-profile School of Business task [34]. The students were motivated to participate because 1) it was an interesting break from standard classroom lectures, 2) they were interested in trying collaborative technology, and 3) the experimental task addressed campus issues in which they perceived a high vested interest.

5.2 Independent Variable

The independent variable in this study was the brainstorming technique used by the subjects. In each treatment, subjects used the same electronic brainstorming software and contributed their solutions anonymously. Participants used the Electronic Brainstorming tool of GroupSystems from Ventana Corp., which allowed them to read the contributions made by others as soon as they were submitted. Since subjects within each group interact with and are able to see the solutions of the other group members, the variety of stimuli that each subject receives is far greater in a group setting than had each subject been working independently.

5.2.1 Non-Directed Brainstorming.

Seven groups engaged in the *non-directed brainstorming* control treatment. In this treatment there were no interactions between the facilitator and the participants during the 40-minute brainstorming session.

5.2.2 Directed Brainstorming.

Ten groups participated in the *directed brainstorming* experimental treatment. During this treatment the participants received 36 scripted prompts (2 prompts derived from each of the 18 known solution dimensions of the task) delivered both orally and in a slide show on a public screen in the front of the room. These prompts are confined to the context of the problem, relate to the criteria for judging solution effectiveness, and have the form, “Now give me a solution that will *effect a such and such result*….” These prompts each address several aspects of our model. Through the scope of each prompt, problem solvers are lead to limit the number of concepts or frames that are salient at any given time, thus reducing overall cognitive load. These prompts may also help subjects take advantage of this lower cognitive load and ‘jump’ to new entry points in their cognitive networks by framing stimuli in various contexts.

5.2.3 Interrupted Brainstorming.

Four groups participated in the *interrupted brainstorming* experimental treatment. During this treatment the participants received 36 scripted prompts delivered both orally and in a slide show on a public screen in the front of the room. The difference between these and the directed brainstorming prompts is that they do not contain the context-relevant solution space decomposition that the directed brainstorming prompts do. There are many phrases that are not contextually neutral and could send participants off thinking about things which are not relevant to the problem they are working on. An example of a phrase which is not context free could be “going to the movies”. When you think of this, you may immediately think of being with your friends, eating popcorn and drinking soda, a movie you have seen in the past, or some new movie you are looking forward to seeing. Each of these thoughts may lead to activation of specific frames which are unrelated to solving the problems of the school of business.

Instead, we crafted a series of interruption prompts that contain contextually neutral "nonsense" phrases made up of random syllables placed together to form "words" and used them during the interrupted brainstorming treatment. Two examples of these interrupted prompts are:

- Somerived medparing doub redence prosidporly.
- Huskmals mar unter ten larace.

These prompts help to provide a "clean slate" to work from and were carefully designed such that each contained the same number of syllables, the same number of "words," and even the same auditory inflection and rhythm as each of the original directed brainstorming prompts. These new, context-free interruption prompts were delivered to this treatment in the same manner and with the same timing as the prompts in the directed brainstorming treatment. All that changed was the *content* of the prompts; reducing each prompt to an interruption for the group members as they worked.

5.3 Dependent Variables

The dependent variables in this study were 1) the number of unique (non-redundant) solutions generated by each group, 2) the concentration of unique solutions generated by each group, and 3) the effectiveness of the solutions generated. The unit of analysis for this study is the four- or five-person block. All items contributed by participants in a single block were pooled to produce a score for that block.

5.3.1 Number of Unique Solutions.

For all treatment groups, we followed a disaggregation policy while distilling the unique solutions from the transcripts of a brainstorming session. With disaggregation, each unique verb-object combination is counted as a separate solution. For example, the solutions

> "We could advertise"
> "Let's advertise in the newspaper"
> "Why don't we advertise on the radio and television"

would be disaggregated into four solutions:

> "advertise"
> "advertise in the newspaper"
> "advertise on radio"
> "advertise on television"

During pilot tests three independent coders using the disaggregation approach achieved a concordance higher than 99%. The number of unique solutions was averaged across all groups within each treatment.

5.3.2 Concentration of Unique Solutions.

To calculate the concentration of unique solutions within an electronic brainstorming session we divided the number of unique solutions by the total number of comments contributed for each group. Thus, had every contribution been a unique solution, the concentration for that group would have been 1.0. The concentration of unique solutions was averaged across all groups within each treatment.

5.3.3 Number of Effective Solutions.

To assess the effectiveness of each solution generated, two raters independently scored each unique solution on a scale of 1 (a solution that cannot be done or has no impact on the problem) to 4 (a solution that is easily implemented and solves the major problems completely). The overall score for each solution was calculated by summing the scores from each rater for that item and then subtracting 2. This made the score for each solution's effectiveness range from 0 to 6. The two coders evaluated all transcripts and found they were in agreement (no more than one point difference) on more than 99.99% of their evaluations.

Solutions which provide only modest or incremental gains for a particular symptom may be useful, but cannot considered "effective." In order for a solution to qualify as an effective solution, it must attack the root cause of the problems. Therefore, we deemed a solution with an aggregate score equal to or greater than four as being an effective solution. An effective solution thus solves the major problems completely, or must be easily implemented and ease the problems a lot. The number of effective solutions was averaged across all groups within each treatment.

5.4 Procedure

All participants in this experiment entered a large computer-equipped amphitheater classroom and selected their own seats. All control groups were run simultaneously in a single session where the facilitator randomly created six blocks of four workstations and one block of five workstations. A similar arrangement was employed for the directed brainstorming groups, with three additional randomly blocked groups run at a later date due to occupancy limitations of the room. The interrupted treatment contained four groups, each composed of randomly created blocks of four workstations. In all cases, the participants selected their own seats and did not know which of the other people in the room were participating in their particular block. The facilitator started a different electronic brainstorming session for each block of students.

In each session the same facilitator greeted the groups and gave each participant a packet of information describing symptoms of problems in an imaginary school of business. The participants were given five minutes to review the packet. After this time period, the facilitator answered any questions the subject had about the information contained in the packet. Then, working from a script, the facilitator instructed the participants on how to use the electronic brainstorming tool, and then gave them 40 minutes to generate solutions to the problems. As described above, the control group had no further interactions with the facilitator until the brainstorming session was complete. The directed brainstorming treatment groups received a series of 36 prompts directing them to seek solutions along some dimension of the solution space, while the interrupted brainstorming treatment groups received a series of 36 "nonsense" prompts. At the end of each session the subjects were debriefed, thanked, and released.

5.5 Results

An independent-samples T-test revealed that the mean number of raw comments produced by participants in the directed brainstorming treatment was statistically significantly greater than the number produced by the non-directed control group [t(15) = 7.04, p<0.001, see Table 1]. T-tests also revealed that teams using the directed brainstorming method produced more unique solutions [t(15) = 13.93, p<0.001] and a higher concentration of unique solutions [t(15) = 2.55, p=0.022] than did teams using the non-directed brainstorming approach. Each of these results is statistically significant (shown in bold in Table 1) and indicate support for both H1 and H2. Groups using the directed brainstorming method produced both a higher number of unique solutions and a greater concentration of unique solutions than groups using a non-directed brainstorming approach. An independent-samples T-test revealed that the number of effective solutions did not differ between non-directed and directed brainstorming treatments. This result does not support H3.

Table 1 also contains the comparisons of mean raw solution count, unique solution count, concentration of unique solutions, and the number of effective solutions between the directed brainstorming and the interrupted brainstorming treatments. An independent-samples T-test revealed that the mean number of raw comments produced by participants in the directed brainstorming treatment was statistically significantly greater than the number produced by the interrupted treatment [t(12) = 11.14, p<0.001, see table 1]. T-tests also revealed that teams using the directed brainstorming method produced more unique solutions [t(12) = 13.12, p<0.001], a higher concentration of unique solutions [t(12) = 4.55, p=0.001], and more effective solutions [t(12) = 2.44, p=0.031] than did teams using the interrupted brainstorming approach. Each of these results is statistically significant (shown in bold in Table 1) and indicate no support for H4, H5, and H6. Groups using the directed brainstorming method did not produce the same number of unique solutions, the same concentration of unique solutions, or the same number of effective solutions as groups using an interrupted brainstorming approach.

6. Discussion

The data suggests some support for Hypothesis 1; that groups using the directed brainstorming method can produce more unique solutions than comparable groups using the non-directed brainstorming method. In this instance, teams using directed brainstorming produced more than 200 percent more unique solutions than those using non-directed brainstorming. The data also indicate some support for Hypothesis 2; the concentration of unique solutions was 37 percent higher with directed brainstorming than with the non-directed brainstorming method. However, the difference between the number of effective solutions in the non-directed and directed brainstorming treatments was not statistically significant; Hypothesis 3 therefore received no support in this experiment.

These results dealing with solution effectiveness seem curious, and may indicate a need for further research of this phenomenon. One possible cause for this result may be a ceiling effect in the problem task given to the

Table 1. Solution Quantity & Effectiveness of Non-Directed (ND), Directed (Dir), and Interrupted (Int) treatments. Numbers shown in bold are significant.

	Number of Raw Solutions			Number of Unique Solutions			Concentration of Unique Solutions			Number of Effective Solutions		
	ND	Dir	Int	ND	Dir	Int	ND	Dir	Int	ND	Dir	Int
Mean	68.4	133.1	55.75	29.0	88.2	24.75	0.48	0.66	0.45	4.00	4.50	2.25
Std Dev	24.70	13.11	5.91	9.47	8.01	8.66	0.22	0.06	0.11	2.82	1.72	0.96
T	**7.04**		**11.14**	**13.93**		**13.12**	**2.55**		**4.55**	0.46		**2.44**
Df	15		12	15		12	15		12	15		12
P	<0.001		<0.001	<0.001		<0.001	0.022		0.001	0.655		0.031

subjects. With the School of Business Task, there exists a single root cause of the symptoms of the problem which all teams tended to identify and address. Perhaps more research is required with a problem domain that contains more or open-ended root causes. Another possibility is that the failure to find significant results for the solution effectiveness measure is an artifact of the small number of groups used in this experiment. More investigation is necessary to differentiate between these possible causes. Overall, Hypothesis 1 and 2 received statistically significant support and Hypothesis 3 received no support. This indicates the directed brainstorming technique appears partially successful in causing more creative solutions.

The comparison between directed and interrupted brainstorming sessions provides no statistical support for our second set of hypotheses. An informal manipulation check performed with the subjects at the end of the interrupted brainstorming session indicated that the stimuli and facilitation technique used during this treatment were indeed effective in interrupting the solution generation processes of the group members as intended. Groups engaged in interrupted electronic brainstorming did not produce the same number of unique solutions as groups engaged in directed electronic brainstorming as Hypothesis 4 proposed. Rather, the directed brainstorming groups produced statistically significantly more unique solutions than did the interrupted groups. The same trend of directed brainstorming groups statistically significantly outperforming interrupted groups was evident for both the unique solution concentration and the number of effective solutions measures. These results do not support Hypothesis 4, 5, or 6. While this experiment fails to support our second set of hypotheses, it does successfully discount the interruption effect as the primary causal factor responsible for the results obtained with the directed brainstorming treatment; thus it seems we have ruled out cognitive resonance as a competing alternative hypothesis to directed brainstorming.

6.1 Brainstorming Response Characteristics

The directed brainstorming participants produced a greater number of both raw solutions and unique solutions, however, the character of their contributions was markedly different than that of the groups engaged in non-directed brainstorming. Almost all the contributions in the directed brainstorming sessions were solution proposals of one form or another, and there was a vastly higher concentration of unique solutions. During non-directed brainstorming the groups tended to make much longer comments, filled with reflections and judgements about the possible consequences of the solutions proposed, indicating that these participants soon forgot their instructions on the “rules” of brainstorming [38]. This suggests there may be some circumstances where non-directed brainstorming would be preferable and others where directed brainstorming might be preferred. It also highlights the point that solution generation is only part of a larger problem-solving process. If a team chooses to conduct directed brainstorming they may want to assure their team process affords them time later to reflect on the implications of their proposals.

A team using directed brainstorming methods must also take pains to assure that the directive prompts they use are truly based on important criteria for the problem at hand. This approach pares the solution space as it extends productivity in the narrower space. It is very likely that sloppy or ill-defined directives could lead a group to produce solutions of little value. Criteria that focus too heavily on symptoms could cause a group to miss the big picture. In directing the participants, one is not only opening their minds to new possibilities, one is excising other possibilities. One must take care not to direct a team away from critical areas of the cognitive network. It may well be useful to first involve the group in developing the criteria for evaluating the effectiveness of their solutions before they begin brainstorming. This could provide a useful completeness check, and could allow the group to create a shared understanding of the meaning of the prompts.

6.2 Limitations

The Cognitive Network Model is based on fundamental assumptions about the nature of the human mind. While this model would suggest that the cognitive processes of creativity would be similar in students and in other populations, theory is often informed by field experience, so one should remain cautious about generalizing beyond the subject population until further tests have been conducted in other populations. Additionally, this experiment uses only one task and only one aspect of the creative process – framing the solution space. One should remain cautious about generalizing to other tasks until this study has been replicated with other kinds of tasks.

7. Conclusion

While several techniques do exist which help people increase creative production, the Cognitive Network Model of Creativity offers a new perspective at a theoretical foundation for these techniques. This model is grounded in mechanisms of human cognition which are hypothesized to exist within all individuals, regardless of their socio-economic status, culture, or other personal and variable attributes.

Given the relatively simple manipulation during the directed brainstorming treatment, the magnitude of the unique solution count and unique solution concentration results suggests we have far more to learn about how to wield GSS tools effectively. This claim has been strengthened with the investigation of the effects of interruption during solution generation, thus discounting one possible alternative hypothesis.

Future experiments are planned to more thoroughly investigate solution effectiveness measurements and the different aspects of the Cognitive Network Model of Creativity with the ultimate intention of providing practitioners involved with creative problem solving with a new set of brainstorming techniques focused on various aspects of creativity.

Of the more than 100 studies published almost none report the details of the techniques used by the facilitator to stimulate groups. Given the large effect that this one technique appears to have on creative solution generation, the GSS research community may learn a great deal by placing a keen focus on technique in addition to technology. It may be that we have only begun to scratch the surface of the value we can deliver to the users.

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