A COGNITIVE NETWORK MODEL OF CREATIVITY: A RENEWED FOCUS ON BRAINSTORMING METHODOLOGY

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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 that 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 (Collins and Loftus 1975; Mednick 1962; Tversky and Kahneman 1974). 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 (Gettys et al. 1987). MacCrimmon and Wagner (1994) 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 that 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 (Couger, Higgins and McIntyre 1993; Marakas and Elam 1997; Von Oech 1992), 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 (Dennis et al. 1996; Dennis, Valacich and Nunamaker 1990; Gallupe et al. 1992; Nunamaker et al. 1991; Valacich et al. 1993). 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 (Buel 1965; Davis and Rimm 1982; Domino 1970; Foster 1971; Guilford 1967; Hocevar 1976; Hocevar and Bachelor 1989; Torrance 1974; Wallach and Kogan 1965). 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

Within a problem solving domain, creativity can alternatively be framed as a property of solutions themselves, which invites exploration into the *mechanisms* of creative thought: *What causes a creative thought to form instead of an uncreative one?* A model focused on the creativity of solutions seems more clearly bounded than a model focused on the creativity of people and ultimately may provide a foundation for engaging the more complex phenomenon: the creative person. Cognitive Psychology offers insights that may help explain what causes a person to generate a creative solution. We have formalized those insights into the Cognitive Network Model of Creativity (Figure 1), the first model that 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) (Tulving 1972), the meaning of the perceived items (as in semantic memory) (Tulving 1972), or the similarity or typicality of the items (Rosch 1975; Winograd and Flores 1986). 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.

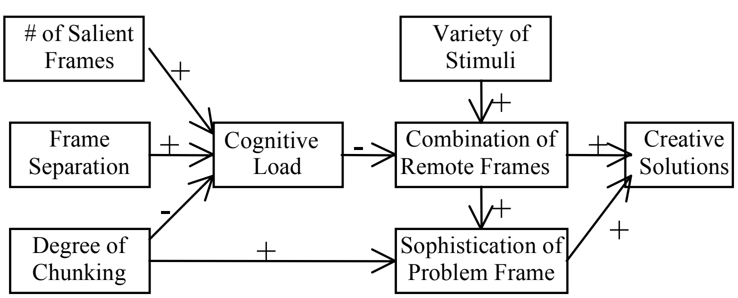

Figure 1. Some of the Causal Relationships Posited by the Cognitive Network Model of Creativity

Networks of Frames. Over time, relationships form between individual frames. These relationships, or links, interconnect frames and result in vast networks that represent our knowledge and experiences (Collins and Quillian 1969; Kounios et al. 1994; MacCrimmon and Wagner 1994). 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 under active consideration at the moment (Ellis and Hunt 1993). We refer to individual frames that currently occupy short-term memory as being *salient* and to the process that causes some particular frame to become salient as *activation*. By traversing the links that 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 (Collins and Loftus 1975). When two or more frames are simultaneously salient they are said to be *associated.*

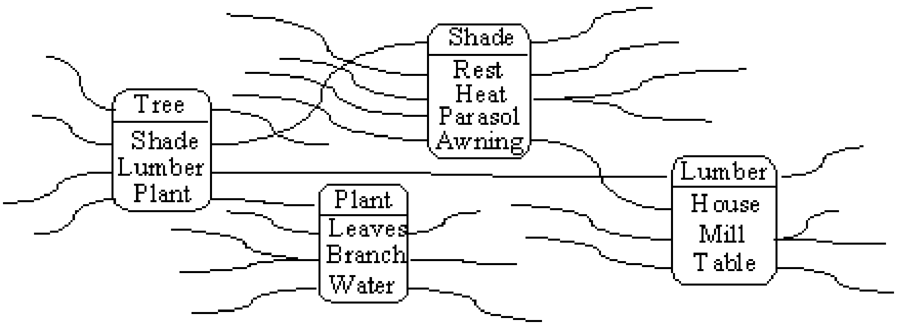

Figure 2. Part of a Knowledge Network

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 that are linked to that concept. This raises the question of how can we lead thinkers to new or different patterns of activation?

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 (Neely 1997; Posner and Snyder 1975), and is relatively independent of the context in which a stimulus appears (Barsalou 1982). This provides a preliminary insight to some of the limitations of problem solving found by Gettys et al. 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 (Mednick 1962).

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 (Barsalou 1982) and requires intention and conscious awareness (Neely 1977; Posner and Snyder 1975). 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 (Elam and Mead 1990; Maltzman 1960; Mednick 1962; Rickards 1988). Indeed, this is the primary foundation of our Cognitive Network Model of Creativity, which indicates 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 that 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) (Norman and Bobrow 1975). In related work, Miller (1956) successfully demonstrated that humans are capable of simultaneously maintaining only a very limited seven plus or minus two "items" in short-term memory. Each of these items are referred to as a *chunk* of information and can range in content from a single letter to multiple frames (Bellezza 1989). Therefore, the more resources that are consumed by holding activated frames or chunks in memory, the fewer 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 that Increase Cognitive Load. Due to the potentially large number of intermediate frames that 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 (Ellis and Hunt 1993). 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 that 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.

Factors that Decrease Cognitive Load. Since chunks can vary in size and complexity (Bellezza 1989), 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 richer set of information (think of Figure 2 as one chunk containing four 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 limiting the number of frames a person tries to manipulate at any given time or directing subjects to use knowledge that 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.

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. THE DIRECTED BRAINSTORMING TECHNIQUE

We propose that the Cognitive Network Model may be useful for guiding investigations and interventions with respect to creativity. If cognitive networks of knowledge form in response to stimuli, then because no two individuals ever have precisely the same experiences, cognitive networks should be different for every individual, providing a strong case for group collaboration when solving complex problems, particularly during brainstorming phases (Osborn 1953). Rickards (1974) further emphasizes several advantages of group brainstorming. These include the observation that individuals each bring different points of view, which can stimulate a greater variety of possible solutions. Also, group brainstorming is most effective in situations where simple concepts in large quantity are needed that address as many aspects of the problem situation as possible. This greater variety of solutions derived from groups often contains more daring strategies as well.

Following from our model, we propose the interjection of *directed brainstorming* prompts during creative solution generation activities directing subjects to focus their efforts and thoughts in specific ways. 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. Finally, since subjects within each group interact with and are able to see the output of the other group members, the variety of stimuli that each subject receives is far greater than had each subject been working individually, potentially resulting in differences in initial framings of solution-relevant concepts that may help problem solvers overcome their reliance on familiar and narrow activation patterns of knowledge and experience.

5. CONCLUSIONS

Over the past several decades, several techniques have been demonstrated to help people increase creative production. However, of the more than 100 studies published, almost none report the causal or theoretical motivations behind the techniques used by the facilitator to stimulate groups. This paper presents a Cognitive Network Model of Creativity and calls for a renewed focus on technique with regard to creativity enhancement. The primary contribution of this model is to offer a new perspective on a theoretical foundation for these techniques. This model is based on fundamental assumptions about the mechanisms of human cognition that are hypothesized to exist within all individuals, regardless of their intelligence level, socio-economic status, or other variable personal attributes. Future experiments are planned to more thoroughly investigate the different aspects of the Cognitive Network Model of Creativity with the ultimate intention of providing a new set of brainstorming techniques focused on various aspects of creativity to practitioners involved with creative problem solving. 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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