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ABSTRACT

While the importance of creativity and innovation in organizations continues to grow, many organizations rely on questionable mechanisms such as group brainstorming and other such techniques to facilitate creativity. Group decision support systems (GDSS) promise to provide an effective means of enhancing group creativity. However, much of the research on GDSS focuses on group processes. This paper takes the position that the individual is the primary determinant of group creativity and develops a model of the individual process of idea generation. This model is applied to GDSS to examine the implications of this perspective on group creativity output.

INTRODUCTION

One of the great fallacies of modern management is that group idea generation is an effective method of supporting creativity in organizations. In particular, group brainstorming (Osborn, 1957) is still widely used for idea generation despite much empirical evidence that it is not as effective as the combined product of individual brainstorming[1] (Diehl & Stroebe, 1991). However, creativity and innovation are becoming increasingly important to organizational competitiveness. Indeed, the much discussed accelerating rate of change surrounding us (e.g., Huber, 1984) calls for a need for new ways of doing things, and an even greater need for supporting creativity (Ackoff & Vergara, 1981). Fortunately, there is evidence that group decision support

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[1] Individuals work on the problem separately. The results are combined and duplicate ideas are eliminated.

systems (GDSS) can overcome the problems associated with group idea generation and make it more productive than individual idea generation (Valacich, Mennecke, Wachter & Wheeler, 1993; Gallupe, Bastianutti & Cooper, 1991; Gallupe, Dennis, Cooper, Valacich, Bastianutti & Nunamaker, 1992).

While it has been empirically supported that electronically supported groups outperform other groups in creative idea generation there currently is not a complete understanding of why this is so. Many authors have examined the implications of factors that have been identified to influence creative output for the design of information systems (e.g., Elam & Mead, 1990). However, few based this examination on an understanding of how creative ideas are actually produced. In essence, previous effort considered the creative process as a black box (e.g., Nagasundaram & Dennis, 1993). In contrast, the purpose of this study is to open the box and examine the process of creative idea generation.

The paper is organized as follows. First, the current state of research on group idea generation is reviewed and the research problem is developed. Next, several different theories of the creative process are integrated to develop a model of the individual's creative process of idea generation. In the third section, this model is used to examine the impact of Group Decision Support Systems on the level of creative output of a group. Finally, conclusions of the research are presented.

GROUP IDEA GENERATION

Past research suggests that nominal groups (collections of individual performances) are more effective at idea generation than face-to-face groups (Diehl & Stroebe, 1987). The primary explanation for this phenomenon is that face-to-face groups incur process losses that individuals do not (Diehl & Stroebe, 1987). Three mechanisms have been proposed to account for these losses: production blocking, free riding, and evaluation apprehension (Diehl & Stroebe, 1987). Production blocking occurs in a group because only one individual at a time can communicate successfully. Therefore, individuals have to wait for others in the group to finish before introducing their contribution, sometimes forgetting or intentionally suppressing their ideas. Free riding occurs when individuals feel that they do not need to contribute for the group to successfully complete its task. Evaluation apprehension occurs when individuals withhold ideas because they fear they will be criticized by others in the group. Research by Diehl and Stroebe (1987) suggests that, while free riding and evaluation apprehension contribute to productivity losses in groups, production blocking accounts for a majority of the productivity loss.

Group Decision Support Systems (GDSS) have been developed to help overcome process losses typically associated with face-to-face meetings (DeSanctis & Gallupe, 1987). Typically, individuals participating in a GDSS meeting can enter their ideas anonymously on a networked computer and at the same time read others' anonymous input on a public screen. GDSS is thought to alleviate process losses by electronic delivery of ideas, comments, and votes, and anonymity of input. Moreover, it may provide process gains by enforcing the use of more effective meeting

procedures. Empirical evidence suggests that GDSS do facilitate productivity in idea generation tasks (Valacich, et al., 1993; Gallupe, Bastianutti & Cooper, 1991; Gallupe, et al., 1992). However, this result is dependent on group size. As group size increases, electronic groups outperform nominal and face-to-face groups (Dennis & Valacich, 1993; Valacich, Dennis & Connolly, 1994).

Given the finding that electronic brainstorming (EBS) works, it is important to understand why (Connolly, Routhieaux & Schneider, 1993). Past research has focused on group process losses (e.g., Diehl & Stroebe, 1987, 1991; Gallupe, Bastianutti & Cooper, 1991), whereas understanding the mechanisms that enhance group creativity remains relatively unexplored. Much past effort examined group idea generation as a group process. Only a limited number of studies have concentrated on the mechanisms that enhance group creativity (e.g., Connolly, Routhieaux, & Schneider, 1993; Dennis & Valacich, 1993). While these studies postulate mechanisms that may enhance group creativity, they do not use an understanding of the group creative process to drive their selection of mechanisms.

An alternative approach is to examine group idea generation as more an individual phenomenon than a social one (Hagasundaram & Dennis, 1993). This new paradigm suggests that the ideas generated by the group are considered a stimulus input to the individual's idea generation effort. The individual uses the stimulus to produce ideas that then become part of the stimulus stream for other members of the group (Nagasundaram & Dennis, 1993). The implication is that the mechanism that enhances group idea generation is the information supplied by and passed among individuals in the group.

In this vein, Hagasundaram and Dennis (1993) developed a model of electronic brainstorming that focuses on the individual's contribution to idea generation. They propose that the way ideas are chunked (grouped) in a stimulus stream will impact both the innovativeness and the number of ideas produced by individuals. More specifically, they suggest that the stimulus stream is the primary determinant of group creativity in electronic brainstorming, with the following consequences: (1) the greater the diversity of the stimulus, the greater the diversity, or innovativeness, of the ideas generated; and (2) the lower the diversity of the stimulus, the greater the adaptability of the ideas generated.

Although a clear advance over previous conceptualizations of the group creativity process, Nagasundaram and Dennis (1993) did not use Newell and Simon's model (1972) to its full potential because their explanation of group idea generation views the individual as a black box: The stimulus input is converted to an idea through unknown means. The nature of the stimulus determines the output without regard to the processing strategy used by the individual to generate an idea. The current study attempts to extend the understanding of group idea generation as an individual rather than a social phenomenon by developing a model of how information is processed during idea generation.

CREATIVITY IN IDEA GENERATION

Understanding creativity in idea generation requires understanding (1) the influences on individuals and groups that can either inhibit or facilitate creativity, and (2) the processes that produce creative results. This paper examines the above factors by using individual level models of creativity to develop an understanding of the process through which creative ideas are produced. The human information processing paradigm (Newell & Simon, 1972) is used to explain the process of creative idea generation. With this focus we assume that idea generation operates in the same general manner as the information processing used to solve problems and that there is no unique cognitive mechanism that produces new ideas. Ideas must be generated just as solutions are generated in problem solving.

Three models of creativity are integrated with Wallas' (1926) description of the creative process: Simon (1966), Amabile (1983), and Findlay and Lumsden (1988). According to Wallas (1926), creative problem solving involves four distinct stages: preparation, incubation, illumination, and verification. In the preparation stage, the individual actively explores the problem and attempts to solve it but does not reach an acceptable solution. The incubation stage begins when the individual stops conscious cognitive work on the problem and engages in other activities. In the illumination stage the individual suddenly and unexpectedly arrives at the solution. Finally, in the verification stage, the individual evaluates the solution. If the solution is not acceptable, the individual iterates through one or more of the stages until an acceptable solution is produced. Only the first three phases of the model are concerned with generating ideas, and only these stages will be examined to develop the model.

Although the Wallas model is descriptive, it does not provide many clues to the processes and mechanisms that actually produce the creative idea. While preparation is certainly important to any problem solving effort, without understanding what occurs during incubation and illumination we cannot explain why these two stages occur, or even if they are required for producing a creative product. Moreover, this model provides insufficient detail for specifying how to enhance creativity in individuals. By integrating other models with Wallas (1926) we develop a description of the creative process of idea generation that can potentially address the above concerns.

INTEGRATED DESCRIPTION OF THE CREATIVE PROCESS

Preparation. The preparation stage of the creative process is an active stage for the individual generating ideas. During preparation, the individual actively explores the problem and attempts to solve it. In this case, the problem to be solved is the generation of an idea.

Newell and Simon (1972) viewed problem solving as a search through a problem space. To solve a problem, the individual must break the problem solving goal into subgoals, those subgoals into subgoals, and so on. The subgoals that the individual uses are generated when she begins to solve the problem. Problem solving consists of searching this set of subgoals for a path that reaches the final goal. In this search, effort is focused on finding methods to achieve the individual subgoals on the path. Figure 1 shows a conceptualization of a problem space.

Figure 1. Example of Problem Space

I: initial state
S: subgoal
G: goal
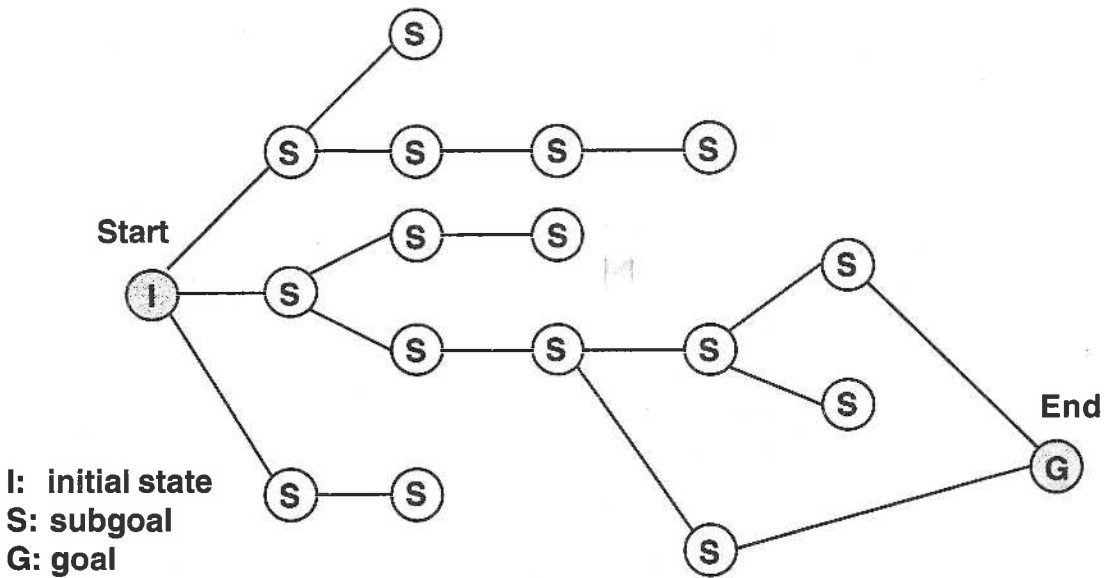
The way the individual moves between subgoals, and branches of subgoals combined with the methods and strategies she uses to achieve subgoals, is her problem solving behavior. Better problem solvers are able to choose paths and use methods that are either more likely to attain the solution or more efficient in attaining the solution. It is therefore conceivable that, just as individuals can be better or worse problem solvers, individuals may be more or less adept at creative idea generation by using better strategies and methods to search different branches of the subgoal tree.

During the search through the problem space the individual also solves portions of the problem. According to Simon (1966), as these portions of the problem are solved they become complete chunks of information. The individual then can successfully store the information as a complete chunk rather than as separate subgoals. In other words, individuals can remember completed or successful paths. As the individual solves successive subgoals, the chunks of information stored in long-term memory may become quite large, completed portions of the problem. This is the mechanism of familiarization, whose significance will become apparent in the next section.

The preparation stage of creative idea generation is the active stage for the participant. Much cognitive effort is expended to create innovative ideas. In this active stage factors external to the individual can influence the creative value of the idea. Amabile (1983) identifies three factors that impact creativity: task motivation, creativity-relevant skills, and domain-relevant skills.

The first determinant of creative output is task motivation, which affects the amount of time and effort the individual puts into searching the different paths of the problem space. A higher level of task motivation may lead the individual to generate more subgoals in the problem space, to explore more paths of the problem space, to apply a better (and more cognitively demanding) heuristic, or to apply, in a more effective way, any creativity-relevant skills she may possess. This additional effort may lead to searching paths that have not been tried, and therefore enhance the creative output level of the individual. In effect, task motivation determines the depth and breadth of the preparation activity.

The second determinant of creative output is the creativity-relevant skills, which may include cognitive style, knowledge of creativity-enhancing heuristics, and work style. These skills impact the types of path explored during preparation. For example, the individual may break her cognitive set (i.e., avoid her typical approach to solving certain problems) (Newell, Shaw & Simon, 1962), and try a subgoal path that typically she would not take for that particular problem, even if that path initially appears to hold little promise. The ability to suspend judgement (Stein, 1975) is also critical because possible solution paths will not be discarded before they are fully explored. If paths are deleted too early in the solution procedure, a potentially creative solution may be eliminated. Creativity-relevant skills can be applied to any task. An individual having these skills will explore paths that individuals not having them will not consider leading to more creative solutions.

The third determinant of creative output is domain-relevant skills - all skills relevant to a particular domain but not to a specific task within that domain. These include both factual knowledge about the domain of interest and technical skills in that domain. The more developed and comprehensive this knowledge base, the more paths or subgoals the individual is able to generate in the problem space. More importantly, these ideas are likely to consist of knowledge that has been tested, thereby producing creative ideas that have a better chance of success. In effect, domain-relevant skills affect the quality of the search through the problem space by generating better subgoals and selecting better paths to examine during the preparation stage.

Incubation. After a period of attempting to solve the problem the individual ceases to work on it and enters the incubation stage. This may be due to frustration, or to other matters taking precedence. In the incubation stage, the individual stops conscious cognitive work on the problem and engages in other activities. This section introduces two processes occurring during incubation that contribute to the production of a creative idea.

Simon (1966) suggests that during the incubation stage, the mechanism of selective forgetting influences the creative problem solving process. As described above, during preparation, individuals actively solve and store large portions of the problem (familiarization). However, unexplored subgoals of the tree generated when the problem was initiated are forgotten, as are the subgoals that were worked on but not successfully achieved. Therefore, selective forgetting effectively trims the subgoal tree that the individual searched during preparation.

Another important process occurs during incubation: spreading activation. This process is explained by Findlay and Lumsden's (1988) theory of the creative process, which postulates that the creative process works on a cognitive structure that organizes knowledge in a semantic network. This structure consists of elements, nodes, and node-link schemata. An element is a specific bit of information in the individual's knowledge base. A node is a concept or chunk of information that represents a collection of elements. A node-link schema is a "unit of knowledge" (or idea) that consists of a node and its related elements. Each element of information may be related to one or more nodes and/or one or more elements. Creativity is a process of activation spreading among the linking elements and nodes. This spreading activation eventually leads to the formation of a new node (a new unit of knowledge) that comprises the elements of the previously unconnected units of knowledge.

Figure 2. The Formation of an Idea
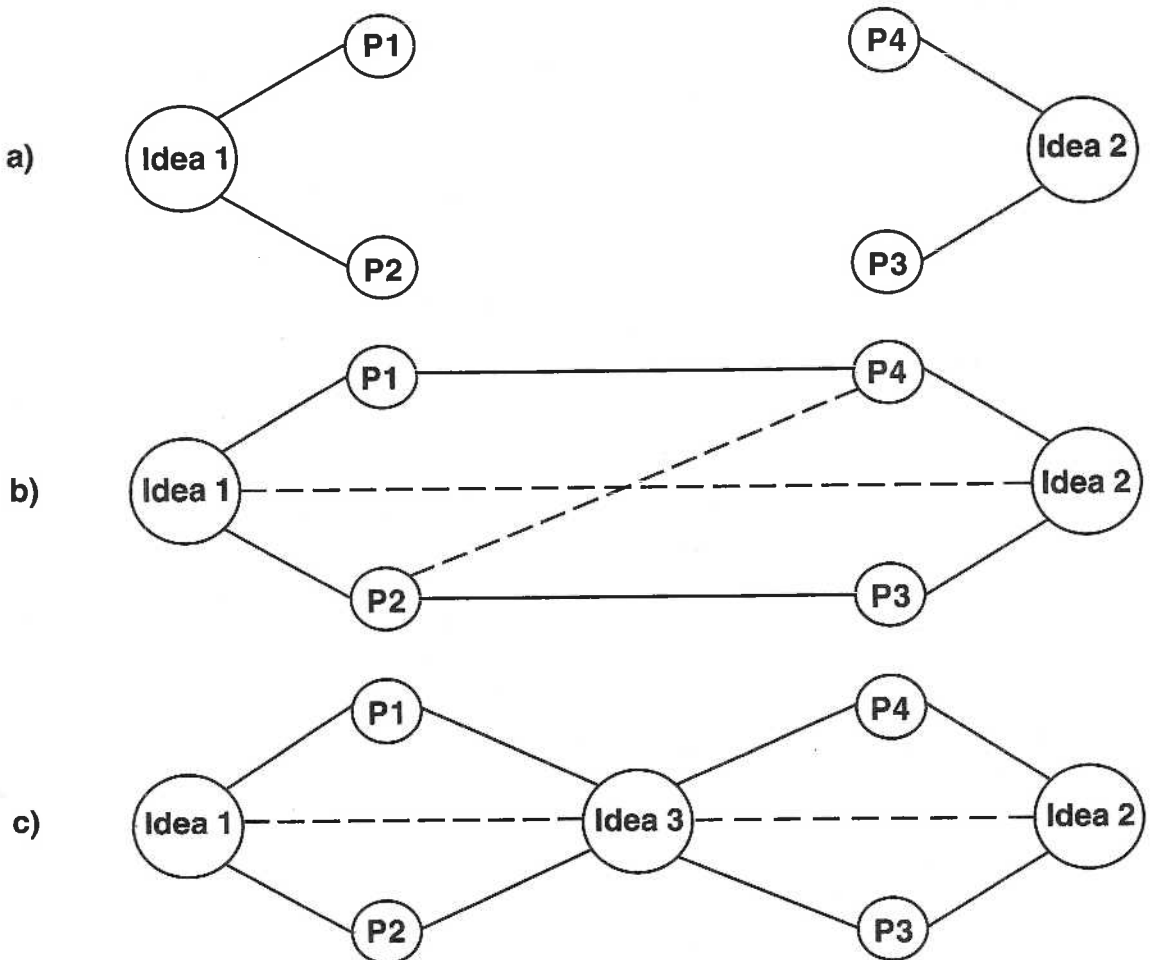
Examining Figure 2 (adopted from Findlay & Lumsden, 1988, pp. 23) helps clarify these ideas. At (a), there is a weak link between Idea 1 and Idea 2. As the individual thinks about one or the other idea, activation passes along that link and the link becomes stronger. As these ideas are continually activated together, links begin to develop between the properties of the two ideas (b). Finally, at (c), a new idea is formed that has all the properties of the two separate ideas. This linking process also occurs during the preparation stage. However, unlike other processes in preparation, this process continues during incubation as the individual thinks about other things that draw on portions of information used in the original problem.

Illumination. The illumination phenomenon associated with creativity occurs when the individual suddenly and unexpectedly arrives at a creative solution to the problem. Simon (1966) and Findlay and Lumsden (1988) contribute competing explanations of the illumination stage.

Simon (1966) suggests that the individual enters the illumination stage when she chooses to address a problem a second time. At that time, the individual is able to retrieve the completed portions of the problem, but must regenerate the subgoal tree. This regeneration may produce a new subgoal path that leads directly to the solution, thereby causing the phenomenon of suddenly becoming aware of the solution, or illumination. However, this explanation suggests that the illumination stage of creativity is highly serendipitous.

Findlay and Lumsden's (1988) spreading activation idea provides a potentially better explanation of a mechanism at work during the incubation stage that leads to the illumination stage of the creative process. During incubation, while an individual works on other problems, weak links among these ideas and other pieces of information in memory are strengthened as that information is used for other thinking. This building of activation and link strengthening continues until a new idea is formed. At this point, activation is high enough to make the idea consciously available to the individual and she suddenly arrives at a solution; hence, the sudden, immediate passage from the incubation stage into the illumination stage.

Summary. Creative idea generation begins with preparation. As in problem solving, the individual attempts to generate an idea by examining the paths of subgoals that may produce an idea. The individual's task motivation, creativity-relevant skills, and domain-relevant skills determine in part the depth and breadth of search of subgoal paths. During the incubation stage, the individual forgets subgoals that were not examined or achieved. The individual continues to develop and strengthen links between the completed portions of the problem and other pieces of knowledge she possesses as she thinks about other things that have weak links to the stored chunks of the problem. The individual enters the illumination stage when a link between the completed portions of the problem and other pieces of knowledge becomes strong enough to be consciously available.

GDSS AND CREATIVITY

The model of the individual process of idea generation developed above will now be used to examine the impact of GDSS on group idea generation. Hagasundaram and Dennis (1993) suggest that the stimulus stream (the exchange of ideas anonymously among group members)

sets group EBS apart from nominal group brainstorming. Therefore, it is important to understand the effect of this stimulus stream on the preparation phase of the creative process. Given the model presented in this paper, the cognitive processing the individual employs during idea generation is a search through a problem space. The data from the input stream could impact that search in three ways. First, the new information may provide a new set of subgoals to explore, with conflicting results. On the one hand, this could lead to innovative ideas because the individual can link the new data to the information already processed. The new data may provide information on how to achieve subgoals in a path, thereby allowing the production of an idea not attainable without the input data. On the other hand, this new data may open so many new search paths that the increased cognitive effort needed to explore them all may be greater than the individual is able to allocate to the task. Therefore, fewer finished ideas are produced. Second, input data may effectively solve portions of the search path, eliminating the need for the individual to explore the complete tree. For example, an idea the individual is trying to generate may be supplied in the input. The individual recognizes the solution and terminates that search. This data then may have the effect of reducing the search. Finally, the input data may not affect the individual at all. There are several explanations for this outcome: (1) the data provides information about paths already searched and discarded; (2) the individual does not understand the data and does not process it; and (3) the individual is working on another path and does not interrupt their processing to handle the new data.

Proposition 1:   *The stimulus stream will increase the productivity of the idea generation system if it provides either new paths to search or a method to achieve a subgoal in a search path that was not previously attainable.*

The model of idea generation presented in this paper stresses the importance of the preparation stage. Much of the impact on the productivity of the system is introduced at this stage. As noted earlier, three primarily important factors are task motivation, creativity-relevant skills, and domain-relevant skills (Amabile, 1983). First, the level of task motivation an individual has will affect the depth and breadth of her search through the problem space. Highly motivated individuals will search more thoroughly and will likely produce more innovative ideas. Further, as noted by Amabile (1983), individuals that are intrinsically motivated toward the task generally produce more creative results than individuals that are extrinsically motivated. Additionally, task motivation can vary not only between tasks, but also within a single task. Therefore, it is paramount that the individual's motivation be kept as high as possible during task execution. GDSS support task motivation by reducing the threat of criticism (due to anonymous input) and by allowing individuals to contribute whenever they want (avoiding production blocking).

Proposition 2:   *Increasing motivation during task execution will increase the number of subgoal paths searched and increase the number of unique subgoal paths searched, thus increasing the innovativeness of ideas generated.*

Second, the individual's knowledge and use of creativity-relevant skills will affect the generation of subgoals in the problem space and the choice of paths searched in that problem space. Individuals with these skills understand that to achieve an innovative or creative response

one must search unique, wild, or even unlikely paths in the problem space. However, because of the unconventional paths examined, the fear of criticism may inhibit the use of creativity-relevant skills in face-to-face groups. The anonymity of electronic brainstorming may reduce these fears.

Proposition 3:   *The use of creativity-relevant skills during task execution will increase the number of unique subgoal paths searched, thus increasing the innovativeness of the ideas generated.*

Finally, the individual's domain-relevant skills will affect the search through the problem space during the preparation stage. Individuals who know more about a problem domain are more likely to produce innovative ideas in that domain. This suggests that to increase the productivity of an idea generation session, participants should be selected based on their knowledge of the domain. This also has implications for the tasks selected to increase the generalizability of experimentation in brainstorming. If domain-relevant skills are important to the ability to be creative in the domain, tasks used should require a certain level of domain knowledge. Otherwise, the ability to be creative is crippled before the experimental treatment is provided.

Proposition 4:   *The productivity of an idea generation session can be enhanced through the selection of individuals with a high level of domain-relevant skill.*

The model of the incubation stage developed in this paper raises important questions. During incubation, unproductive ideas are forgotten and potential solutions are linked with other ideas to constitute creative responses. A critical issue discussed in the creativity literature is the non-deterministic and sometimes long time necessary for these processes to take place. In a real-time electronic brainstorming session, the time available for incubation is clearly less than when individuals are separately involved in a comparable creative effort. A possibility is that the processes of selective forgetting and linking ideas normally followed in the incubation stage may be replaced in an electronic brainstorming session by the faster process of idea exchange. Idea exchange may combine the two required processes. The new idea forces the individual to stop thinking about her current idea (forgetting) and brings a new idea into consciousness that may be linked to the most current idea, or to a chunk of information stored in memory, potentially producing a creative response.

Question 1:   *Does the process of idea exchange through the stimulus stream effectively replace the processes of selective forgetting and linking used in "normal" creativity efforts?*

Question 2:   *Is the incubation stage required to produce innovative ideas?*

These are important questions for three reasons. First, while using a GDSS there is no traditional incubation stage. A typical electronic brainstorming session operates in real-time. A question is posed and individuals enter their ideas into the computer. The computer exchanges an idea entered by one individual for an idea entered by another individual; then the first individual enters another idea. Individuals generally do not leave to work on other items. This may not allow enough time for selective forgetting to occur. Second, without the incubation stage, there is no time to forge connections between ideas, possibly decreasing the potential

for developing truly creative ideas. Finally, all the ideas generated by each individual are recorded. This is another reason why the selective forgetting process, an important facet of the creative process, may be hindered.

Additionally, this description of the creative process does not suggest how much time must be spent in incubation. Does incubation require seconds, minutes, hours, or days? This has critical GDSS design implications. On the one hand, if incubation absolutely requires more than a few minutes, a single continuous electronic brainstorming session is not likely to produce truly creative responses. On the other hand, other processes that are part of electronic brainstorming may compensate for this problem. For instance, the exchange of ideas may effectively substitute for the selective forgetting process. As one idea is submitted and then replaced by another individual's idea, an idea that was not working may be replaced (forgotten) with the new idea. Moreover, the exchange of ideas among individuals may increase the number of ideas that can be linked, providing ideas to individuals that they may not have had themselves.

Finally, exchanging ideas as soon as they are developed and moving on to other ideas may not allow adequate time for preparation, or for investigating a particular solution path. Because of this, the individual may never build a large chunk of information as a single idea in memory and be unable to produce a creative response by linking it to other ideas.

CONCLUSION

Group problem solving is becoming more pervasive in organizations. Companies are reorganizing or re-engineering work from individual tasks to teams. To be effective in today's rapidly changing business climate, these teams must develop innovative solutions to organizational problems. Considering that the creativity output of face-to-face groups has been shown to be less than that of individuals working separately, it has become important to provide better alternatives. Group decision support systems have emerged as a viable option to regular face-to-face groups, because GDSS may be able to eliminate process losses that could limit group creativity.

Crucial in this effort is understanding how GDSS impact the creativity of the output. Recent models have suggested that it is imperative to examine the process of individual creativity in order to attempt to improve the creativity of GDSS-assisted meetings. Until now, the proposed models tried to explain the creativity phenomenon on an input-output basis. This paper, on the other hand, proposed a description of how individual idea generation works, therefore enabling the authors to develop propositions which, when studied empirically, may shed light on key questions not yet addressed in the area of creativity, with direct consequences for the design of future GDSS.

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