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# COLLABORATIVE STIMULATION OF MEMORY RETRIEVAL IN CREATIVE DESIGN

J. Sauder and Y. Jin

Department of Aerospace and Mechanical Engineering, University of Southern California, Los Angeles, USA

**Abstract:** Collaboration has often been attributed to encouraging creativity. This assumption is explored by investigating the influence of interactions between designers on creativity relevant cognitive processes. It is proposed that external design entities stimulate creativity relevant cognitive processes through collaborative stimulation. This paper specifically explores how the cognitive process of memory retrieval is stimulated through collaboration by memory stimulation. It is hypothesized that collaboration leads to more memory stimulation than working alone. A study using protocol analysis has been conducted to evaluate this claim.

***Keywords:*** *collaborative creativity, creative cognition, memory*

## 1. Introduction

Collaboration has been often assumed to encourage creativity; a concept which can be seen in workplace practices and books. But there is often the unanswered question, "*How* does collaboration influence the creative process?" This work provides one perspective answering this question.

Collaborative creativity and creative cognition are the foundations this research is built on. One of the most well known areas in collaborative creativity is brainstorming. While brainstorming research has shown the method reduces the quantity and quality of creative ideas due to social inhibition and procedural issues (Diehl & Stroebe 1987; Mullen et al, 1991), it has also found that collaboration creates positive stimulating effects (Brown et al., 1998; Dugosh, et al., 2000). Non-brainstorming research refers to this stimulation as bridging (Sarmiento & Stahl 2008), or purposeful action to overcome an obstacle. Idea retention also improves by collaboration, through the effect of group remembering (Sarmiento & Stahl 2008).

How collaboration influences memory retrieval, beyond retention, is important as retrieving past memories has been identified as the fundamental element in new idea generation (Nijstad & Stroebe 2006). Concepts individuals are exposed to directly influence the ideas they remember, and collaboration increases exposure to a diverse set of concepts (Satzinger et al, 1999). In addition to diverse exposure, a collaborative group has a larger combined set of memories than an individual, meaning there is a more diverse set of memories from which to draw (West 2002).

The creative cognition approach was established by Finke, Ward and Smith (1996). Their Geneplore model divides creative cognitive process into generation and exploration, which occur in a cyclical manner, until pre-inventive structures become knowledge structures (complete concepts). Benami and Jin (2002) and Jin and Benami (2010) expanded the Geneplore model to engineering design by identifying applicable creative cognitive processes: memory retrieval, transformation, association (from generation) and problem analysis, solution analysis (from exploration).

However, a gap exists as work in creative cognition explores cognitive process of each designer (Finke et al., 1996; Jin & Benami, 2010), but does not explore the influence of collaborative interactions. On the other side, collaborative creativity examines team interactions, but treats individuals as “black boxes”, not investigating individual cognitive processes (Pirola-Merlo & Mann 2004; West 2002; Sarmiento & Stahl 2008). Even Shalley and Perry-Smith (2008), who explore team creative cognition and how individual creative cognition is infused into it, treat individual creative cognition abstractly by not exploring individual cognitive processes. Similarly Stempfle and Badke-Schaub (2002), who take a cognitive approach to the engineering design process, break down thinking operations into categories but not individual cognitive processes. This work bridges the gap by proposing a model which extends creative cognition to collaborative creativity.

## 2. A model of collaborative stimulation in engineering design

The Collaborative Cognitive Stimulation (CCS) model is based on Jin and Benami’s (2010) Generate-Stimulate-Produce (GSP) model of creativity in conceptual design. Their model consists of design entities, which stimulate cognitive processes (both generative and exploratory), which produce design operations, which generate new design entities (figure 1 left). The cycle continues until pre-inventive design entities (undeveloped concepts) mature to knowledge entities (the completed design).

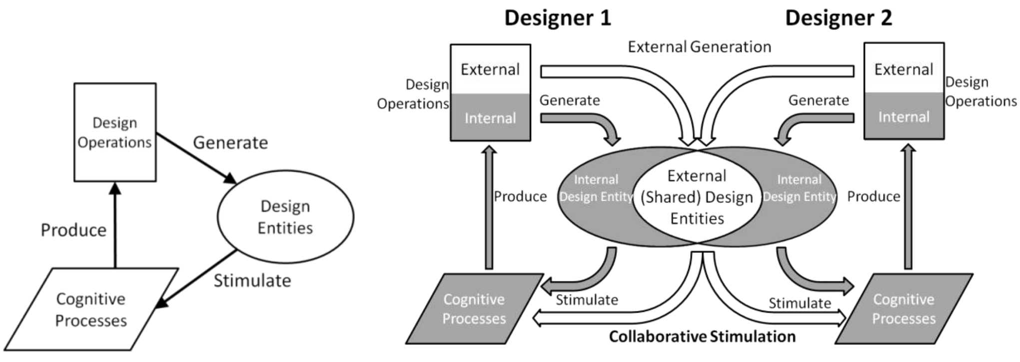



**Figure 1.** GSP Model (left); CCS Model (right)

The CCS model expands the GSP model to collaboration by proposing that interactions between designers occur through external design entities. It can be observed (figure 1 right) how each designer engages in the same individual processes, but ideas are shared through external design entities. The CCS model hypothesizes that external design entities stimulate cognitive processes through collaborative stimulation.

### 2.1 A closer look at collaborative stimulation

There are multiple types of collaborative stimulation, which can be divided into two categories: *staging* (which provides an initial set of conditions for cognitive processes to occur) and *promoting* (which encourages the individual to perform a cognitive process). Types of staging stimulation include *memory stimulation*: ideas developed stimulating memories in individuals (Nijstad & Stroebe 2006). This can occur collaboratively or individually. Also included is *seeding*: a design entity from a collaborator is infused into an individual's working memory. From this seeded idea, knowledge can be applied to new domains and new ideas generated (Nijstad & Stroebe 2006). Types of promoting stimulation consist of *accommodating*: an effort to incorporate a collaborator's ideas into their own as they are viewed as valuable or to come to a general agreement because of an argument (Jin et al. 2006). Another type of promoting stimulation is *clarifying*: an individual senses their collaborator does not understand an idea and the attempt to clarify their idea by explaining it in a different way, like using an analogy, which leads to further development of the idea. Analogies have often been used to explain concepts (Glynn & Takahashi 1998). Also included in promoting is *collaborative completion*: occasionally an individual is unable to complete a cognitive process set on their own therefore their collaborator fills this gap, by performing the cognitive process they are unable to complete. This has also been called bridging (Sarmiento & Stahl 2008).

Each type of collaborative stimulation is speculated to have a different influence on each cognitive process. The likelihood of each type of collaborative stimulation leading to the stimulation of cognitive processes is shown in figure 2. Only the stimulation of generative cognitive processes of memory retrieval (remembering an idea from the past), association (drawing relationships between two design entities), and transformation (alternating a design entity) (Jin & Benami 2010), have been explored thus far.

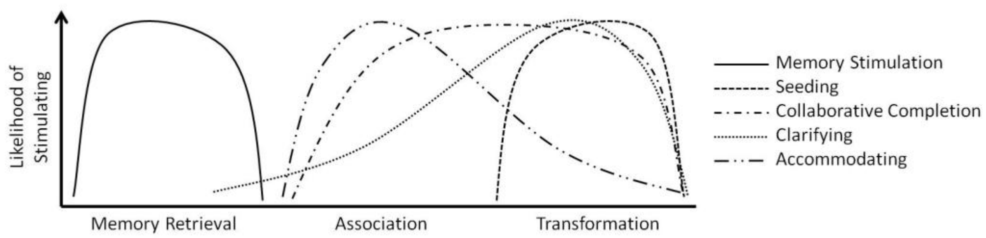



**Figure 2.** Illustration of relationships between collaborative stimulation and cognitive processes

This paper focuses on how collaboration influences the stimulation of memory retrieval. As can be seen from figure 2, collaboration is most likely to influence memory retrieval through memory stimulation. Therefore this type of collaborative stimulation will be investigated in detail.

## 3. Collaborative stimulation of memory retrieval

Memory retrieval occurs when a memory from the past (in long term memory) is brought into the present (working memory). Memory retrieval is important for creative idea production, as designers begin idea generation by remembering a past idea (Nijstad & Stroebe 2006). Memory retrieval can recall two kinds of memories: past memory retrieval and retention. Past memory retrieval consists of remembering ideas from the designers' past engineering or life experiences which have not yet been applied to the project. Retention consists of remembering ideas which were used earlier in the project, but then ignored or forgotten (Sarmiento & Stahl 2008).

### Hypotheses

Two hypotheses regarding the stimulation of memory retrieval are proposed.

> H1: "External design entities generated by an individual's collaborators stimulate memory retrieval through the collaborative stimulation of memory stimulation"
>
> H2: "Design entities are more likely to stimulate memory retrieval in the collaborative setting than in the individual setting due to memory stimulation"

H1 proposes a process which occurs when a design entity from a collaborator stimulates a past memory retrieval or retention. A design entity consists of a form, function or behavior (or a mix of these three elements) (Benami & Jin 2002). In order to test H1, it will first be shown that collaborative memory stimulation exists, and secondly that memory stimulation from external design entities stimulates the cognitive process of memory retrieval. It should be noted that individual memory stimulation can also occur. Individual memory stimulation is different from collaborative memory stimulation, as it occurs when a memory retrieval is stimulated by the individuals own design entity, instead of a design entity from their collaborator.

H2 proposes that individuals collaborating are more likely to have design entities stimulate the memory retrieval process (either past memory retrieval or retention) than individuals working alone. It is believed that collaboration will stimulate past memory retrieval because there is increased exposure to diverse concepts (Satzinger et al. 1999) and a larger pool of memories between collaborators to be stimulated by design entities (West 2002). Retention of design solutions developed earlier in the project is believed to increase because of group remembering (Sarmiento & Stahl 2008). This is where the group provides a greater collective effort to retain ideas. Interestingly, in the individual setting, it has been observed that designers often do not retain their most innovative initial solutions and pursue less innovative ideas to completion (Jin & Benami 2010). H2 will be tested by comparing how often design entities stimulate memory retrieval in the individual and collaborative settings.

## 4. Experiment approach and results

### 4.1 Experiment design

In order to test the hypotheses, it was necessary to compare those who worked individually to those who worked collaboratively. An experiment was conducted on seven subjects, who were divided into the two groups, an experimental group that collaborated (two teams of two) and a control group that worked individually (three subjects).

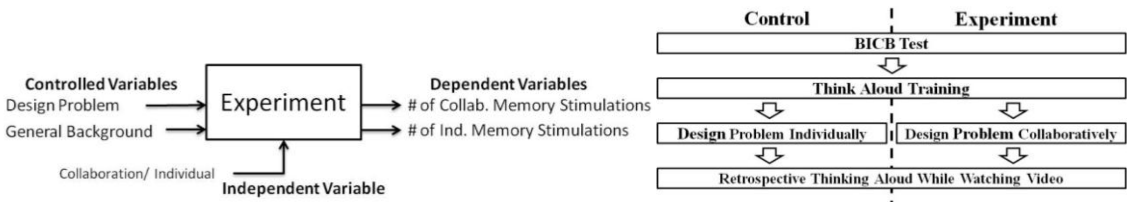



**Figure 3.** Experiment design (left) and experiment procedure (right)

The dependent variables of this study were the number of collaborative memory stimulation cases and the number of individual memory stimulation cases.

The independent variable in this experiment was whether the subjects were collaborating (the experimental group) or if they were working by themselves (the control group). The experimental group collaborated with each other in teams of two on the design problem, whereas the control group worked on the design problem alone.

The controlled variables in this experiment design were the design problem and general background of the subjects. The design problem given was to develop a system or device that would reduce traffic congestion (see full problem in appendix). The subjects had similar backgrounds being mechanical engineering majors with some exposure to design theory and methodology. Also, all lived in the greater Los Angeles area, so they were familiar with traffic congestion.

**4.2 Procedure**

The study of cognitive processes in design activity has been a common procedure in many studies. The general approach is to use protocol analysis, where subjects think aloud while they are designing, and then transcripts of their thoughts are analyzed (Cross et. al. 1997). To analyze collaborative activity, dialogue transcripts have been employed. Sometimes, actual protocol analysis is done, applying a coding scheme to the dialogue transcript (e.g. Stempfle & Badke-Schaub 2002) while other times the conversation is only analyzed for social interactions (e.g. Cross et al. 1997). However, these approaches do not identify specific cognitive processes occurring in the mind of the individual. There are two challenges to accomplishing this: (C1) How can a subject verbalize their thoughts and not influence their collaborator? (C2) How can cognitive processes be observed when individuals are required to talk with each other and thus cannot continuously verbalize their thoughts?

To address these challenges, a retrospective approach to protocol analysis was taken. The subjects were asked to retrospectively verbalize their thoughts from the design process while watching a video of their actions. Retrospective protocols have been found to produce similar results to concurrent protocols (Gero & Tang 2001). The video assisted in providing both verbal and visual cues, to help the individuals remember what they were thinking at that moment. Subjects were also provided with their sketches to assist their memory. As the verbalizations occurred after collaborating on the design problem, the subject's verbalizations did not impact their collaborator's thoughts (solving C1). Conducting the thinking aloud after collaborating on the design problem also allowed the subjects to collaborate in a natural environment, and allowed for continuous verbalization of their thoughts (solving C2).

Before coming to the study, participants were given the Biographical Inventory of Creative Behaviors (BICB), to determine their individual creative potential. This test was reviewed with other creativity tests by (Silvia et al. 2011), and found to be both quick and effective. The results of the BICB were used to create control and experimental groups with similar creative potential and to set up teams which had similar average BICB scores.

When first arriving at the study, participants were given training in verbalizing their thoughts. This training session consisted of working through several simple problems, while thinking aloud. Then participants in the experimental group were given a design problem with their partner, while individuals in the control groups were given a design problem to solve alone. Participants were provided with a pen, paper, and the design problem statement. Both the control and experimental groups were recorded on video as they worked through the problem.

Immediately after the completion of the design problem, the subjects were given the video and asked to retrospectively verbalize their thoughts while watching it. The retrospective verbalization of their thoughts was recorded for later transcription. While the control subjects could have done the more traditional concurrent think aloud technique while going through the design problem, in order to ensure similarity between the control and experimental groups, they performed retrospective thinking aloud as well. The entire procedure is shown in figure 3 (right).

### 4.3 Data analysis

The video and audio recordings were saved, and the audio recordings of the retrospective analysis were transcribed after being divided into 30 second segments. Dividing the transcripts into segments allowed the comparison of specific points in the retrospective audio to specific points in the video, which was particularly valuable in the collaborative setting. A protocol analysis approach was taken to analyze the transcripts. The typical approach to protocol analysis is to segment the entire episode (Gero & McNeill 1998). However, as the authors were interested in only the stimulation of the memory retrieval by design entities, a hybrid three step approach was taken to reduce analysis time: identifying design entities, cases of memory retrieval and cases of memory stimulation.

#### *4.2.1 Identifying Design Entities*

A design entity was identified as an idea having a form, function, and/or behavior (Benami & Jin 2002). Sometimes, design entities were accompanied by sketches, which assisted in identification. For example, consider the protocol below where a subject in the control group describes a design entity just created. “I was thinking, yeah, you can have, yeah, multiple layers of traffic. High speed, medium speed, and low speed.” In this protocol, the design entity could be identified as having the form of multiple layers (show in figure 4). It also had the behavior of a different speed for each layer and the implied function of reducing congestion.

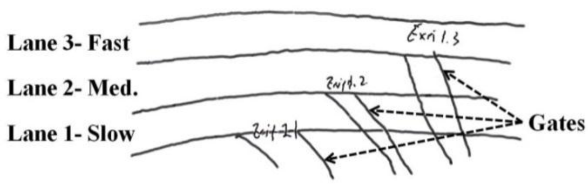



**Figure 4:** Sketch of Multiple Layers of Traffic

#### *4.3.2 Identifying Cases of Memory Retrieval*

A second sweep was done through the protocol to identify all the cases of memory retrieval, which consists of the two categories of past memory retrieval and retention of earlier memories. For example, two collaborators (J and M) were working on a design entity they called “Active GPS”. The active GPS would direct drivers to their destination and reduce traffic by assigning cars to different routes. M starts the by suggesting the concept again, after the idea had been conceived by J earlier.

> M: I’m down with GPS?
>
> J: Ok, we might as well use the GPS then. Except this wouldn’t be all that different from the current GPS, although it would have active management rather than just warning, warning people

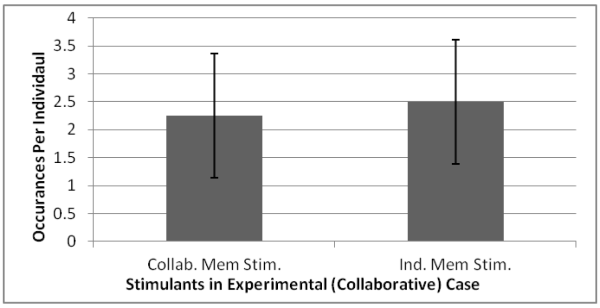
M’s protocol for this conversation was as follows: “I decided to go with the GPS which kind of felt better. So here we... So once we chose the GPS, we kind of expanded the idea.” This is an example of memory retrieval, with the specific case of retention, as J and M are returning to the design entity active GPS. However, M also has a new case of past memory retrieval which follows the conversation. “So now I was just kind of thinking of having some incentives for people doing what you tell them to do. Because in my experience if you tell something to do something and they see a solution, and think that it is better, the overall good is something they don't keep in mind.” Here, when considering how the active GPS would work, M was drawing from his memory of situations where people would not do what is in the best interest of others seeking their own best interest.

*4.3.3 Identifying Cases of Memory Stimulation*

To find memory stimulation cases, the protocol was examined for design entities followed by memory retrieval. If the design entity inspired the memory retrieval, then the case was determined to be memory stimulation. Memory stimulation could occur collaboratively and individually. Collaborative memory stimulation occurred when the inspiring design entity was developed by a collaborator. Individual memory stimulation occurred when the inspiring design entity was created by the subject. Collaborative memory stimulation only occurred in the experimental condition.The “Active GPS” example just mentioned is a case of collaborative memory stimulation. The design entity of “Active GPS” stimulated M to have a memory retrieval of his past experience interacting with individuals; specifically that “the overall good is something they don’t keep in mind”. A case of individual memory stimulation occurred immediately after the first example of “multiple traffic layers”. The subject’s protocol follows: “So, at this time I was thinking some kind of gate traffic that could determine if the vehicle was exiting, or could make some sort of sound if the vehicle was exiting. Or if the vehicle was not exiting, then the gate won't open. There won't be any physical connections on this road. I realize it’s almost impossible, it’s like Battle Cruisers, it’s like airplanes get in get out at the same time. You have to have elevators to raise and lower” This example shows how the design entity of “gate” stimulated the memory retrieval of “Battle Cruiser”. This memory led to a solution analysis that “gates” would not work. This is a case of individual memory stimulation, as the design entity “gate” was created by the subject.

**4.4 Results**

In analyzing the data, it was found that memory retrieval was stimulated by the collaborative stimulant of memory stimulation as described. The experimental condition averaged 2.25 collaborative memory stimulations per designer (SD=1.71) and 2.50 individual memory stimulations per designer (SD=1.29). The difference between these two is not statistically significant; t (2) =0.33, p = 0.05. These results are shown in figure 5 (left).



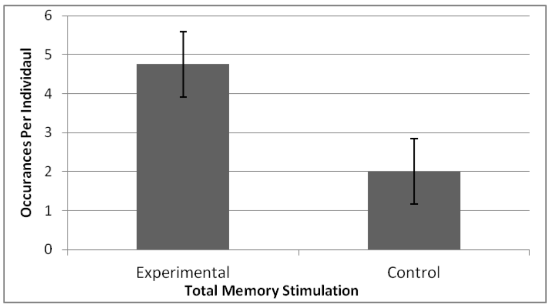




**Figure 5:** Experimental memory stimulation breakdown (left) and control vs. experimental (right)

In comparing the control group to the experimental group (figure 5 right) for memory stimulation occurrence, it was observed that the control group had 2.0 memory stimulations per person (SD=1.00), whereas the experimental group had 4.75 memory stimulations per person (SD=2.21). Using a t-test to compare the results the difference is statistically significant; $t(5) = 2.2$, $p = .05$.

Three other pieces of data collected were the BICB scores, the total number of considered solutions, and the time on the problem. Complete solutions were taken as being unique ideas (made up of one or multiple design entities), with form, function and behavior (Jin & Benami 2010) providing an answer to the design problem. The experimental group had an average BICB of 7.5 and generated 3 solutions per designer. The control group had an average BICB of 11.3, and generated 12.3 ideas per designer. Collaborative exercises lasted an average of 25 minutes (ranging from 21 to 30 minutes) where as individual exercises lasted an average of 35 minutes (ranging from 22 to 43 minutes).

## 5. Discussion and conclusion

From the results, it appears that both H1 and H2 are accurate. Through the analysis it was clear that design entities stimulated memory retrieval through memory stimulation, verifying H1. It was also found in the experimental case that individual and collaborative memory stimulation were about equally as likely to occur when collaborating. It was observed that design entities are more likely to stimulate memory retrieval through memory stimulation in the collaborative setting, than in the individual setting. When using a t-test to compare the number of memory stimulations occurring in the control and experimental cases, the difference was found to be statistically significant, verifying H2. This is interesting as the control group created more solutions, spent more time on the problem and had a higher average BICB score, which one would think would lead to more memory stimulation. These considerations emphasize the important influence of collaboration on memory stimulation. It should be noted because of the small number of data points (7 participants) these results should be taken with caution. The findings are important though, as memory retrieval provides the foundation on which designers build new ideas. By improving the opportunities for memory retrieval through collaborative stimulation, the potential of the designer's ability to generate creative ideas increases. In conclusion, while the data from this experiment trends that the hypotheses are correct, much work remains to be done. First, a second verification of the findings in this study should occur with more subjects (providing more data points) and multiple coders (to check inter-coder reliability). An experiment involving 17 subjects has already been conducted, and the authors are currently coding the results. Second, details on the additional collaborative stimulants need further development. Third, after the stimulation of generative creative cognitive processes has been defined, it should further be explored how collaboration stimulates the exploratory cognitive thought processes Jin and Benami (2010) identified. This will provide a more complete answer to the question posed at the beginning of this paper "*How does collaboration influence the creative process?*" This work is at the tip of a very exciting iceberg, discovering new depth about the collaborative creative process in design by taking a cognitive approach.

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