Idea Expander: Supporting Group Brainstorming with Conversationally Triggered Visual Thinking Stimuli

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ABSTRACT
Creativity is central to much human problem solving and innovation. Brainstorming processes attempt to leverage group creativity, but group dynamics sometimes limit their utility. We present IdeaExpander, a tool to support group brainstorming by intelligently selecting pictorial stimuli based on the group's conversation The design is based on theories of how perception, thinking, and communication interact; a pilot study (N=16) suggests that it increases individuals' idea production and that people value it.

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Creativity support tool, group brainstorming

ACM Classification Keywords
H5.3 Group and Organization Interface: Computer-supported cooperative work

General Terms
Design, Experimentation, Human Factors, Performance

INTRODUCTION
Generating new ideas is at the core of many types of work. Researchers think of new topics to study, new ways to analyze data, and new experimental paradigms to advance their work. Business teams consider new products, new features for existing products, new ways of advertising and better ways of producing their wares. Designers and engineers seek innovative solutions for multiply constrained design problems.

Identifying new ideas can be difficult due to individuals' limited vision, knowledge, experience, motivation and time. Collaborative teamwork that pools and integrates efforts from multiple individuals is thus considered a useful way to approach creativity. Some forms of creativity cannot even happen without the involvement of group members, such as improvisational jazz music performance in a band.

Group brainstorming that engages individuals to generate ideas jointly has been one of the most popular teamwork techniques for supporting creative idea generation. In brainstorming groups, individuals focus on generating a large amount of ideas without worrying too early in the process about whether those ideas can be eventually used to solve the given problems. The goal is to accumulate an abundance of ideas that the group can sift through later.

From a system point of view, group brainstorming can be viewed as a self-sustained social creativity system in which the producer and consumer of ideas reside at the same locus. Conversational interactions allow multiple thinkers to exchange their ideas. Overhearing other people's ideas may stimulate individuals' thinking [5] and consequently make more ideas available as stimuli to the group members.

Successful group brainstorming is therefore an iterative process that involves two main stages, *idea exchange* at the social level and *idea expansion* at the cognitive level. Idea expansion, generating new ideas based on existing ideas, is a crucial stage that both determines the final product and generates new stimuli that keep the brainstorming process going. Group brainstorming is a fragile process, because generating new, unconventional, or even deviant ideas can be difficult, both in terms of cognitive and social psychological processes [2][5].

In this paper, we propose to support group brainstorming and enhance group creativity by shifting some agency of idea exchange and idea expansion to computers, thereby extending the creative power of brainstorming groups. We describe IdeaEpxander, a system that creates an extra visual communication channel that retrieves and shows pictorial stimuli dynamically based on conversational content. Its design is informed by cognitive theories that account for how visual perception, communication, and thinking interact in the context of group brainstorming. We evaluate the system with a laboratory study. In a 14 minute brainstorming session, IdeaExpander helped individuals working in dyads each generate two more ideas (about 20%) than without IdeaExpander. This shows that IdeaExpander is potentially helpful, especially as enhancing ideation in dyads has been shown to be difficult [4].

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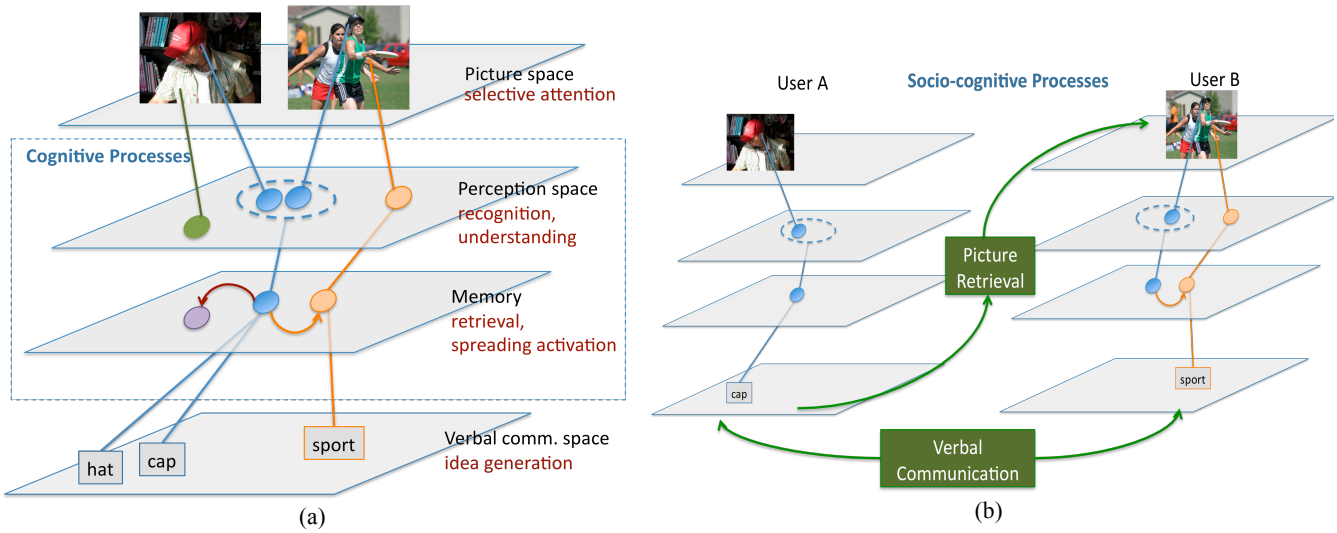

Figure 1. Cognitive and socio-cognitive processes mediated by IdeaExpander. (a) Cognitive processes of expanding ideas from picture stimuli. (b) Socio-cognitive processes of exchanging and expanding ideas with conversationally retrieved pictures.

SOCIO-COGNITIVE PROCESSES IN BRAINSTORMING

Group brainstorming essentially involves idea generation at the individual level and social interactions at the group level. A complete picture of group brainstorming processes would therefore require an understanding of cognitive factors, social factors, and how social inputs may influence individuals' thinking processes and outcomes.

At the cognitive level, theories posit that human semantic memory can be represented as a network structure in which concepts are nodes with associative links with each other [e.g.,,8]. A fundamental cognitive operation to generate ideas is to retrieve concepts from associative memory. Given the network structure of memory, retrieving one concept may then make other interconnected concepts more accessible and easier to retrieve. For example, thinking about the concept "pet" may activate the concept "cat," which in turn might activate concepts like "cute" and "playful." In this way, activation of one concept spreads through the memory network, with the degree of activation attenuating with successive steps across nodes [8].

Spreading activation helps explain why brainstorming in groups is useful. Overhearing another person's idea helps trigger the same concept in the overhearer's associative memory, thereby initiating the spreading activation process in a subset of memory that has not yet been explored by the individual, the *cognitive stimulation effect* [8]. In this paper, we term the cognitive process of generating new ideas based on earlier ideas as *idea expansion*.

However, despite the potential cognitive benefits, group brainstorming often fails to actually help people generate quantitatively more or qualitatively better ideas than what they are able to do on their own [2]. There are negative social side effects of working in groups, such as evaluation apprehension (the fear of expressing ideas due to peer evaluation pressure) and production blocking (taking turns to speak up) [2]. These social side effects are primarily due to the fact that people tend to view group brainstorming as a social activity, not just an impersonal event for idea exchange. As a result, social processes like impression management and interpersonal communication play a significant role in brainstorming groups. Because these social barriers make it difficult to exchange ideas fully, there may be *fewer* external stimuli available to stimulate thinking and make idea expansion happen.

A three-step vicious circle arises from the interplay between these social and cognitive processes:. (1) Social inhibition of idea exchange: Individuals may not exchange all their ideas due to peer evaluation pressure; (2) Poverty of stimuli: Thus, fewer ideas are made available as stimuli for others' idea expansion; (3) Iterative convergence and fixation: As group brainstorming progresses, the poverty of stimuli leads to convergence of thoughts and may make it even more difficult to think of new ideas.

Early research on brainstorming support mostly focused on addressing the social inhibition issue by reducing peer pressure as much as possible [4]. Limited attention has been paid to ways of increasing cognitive stimulation.

THE IDEA EXPANDER MODEL

We take an innovative system approach to support idea exchange and idea expansion by widening the bandwidth between group members with a conversation-aware visual communication channel. That is, IdeaExpander adds a picture space that is *shared* by group members and is sensitive to conversational content. An agent chooses pictures related to ideas that have recently been discussed, which may then stimulate the generation of new ideas.

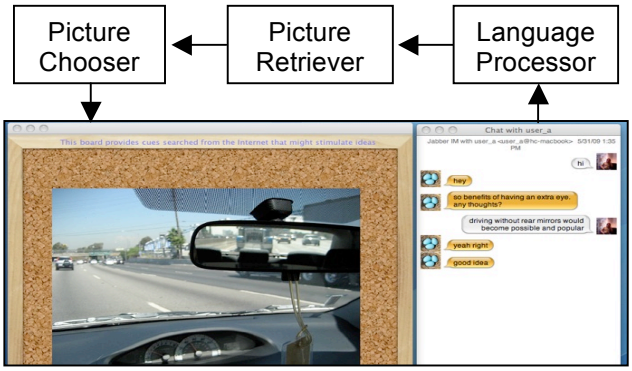

Figure 2. IdeaExpander screenshot and high-level architecture. The system monitors the group conversation (right) and selects pictures to display to the group (left).

Figure 1(a) shows the cognitive processes that bridge the picture and the verbal communication space. We explain the process by following Figure 1(a) from top to bottom, starting at the picture space. We choose pictures as a stimulus because cognitive theories and studies suggest that human attention and perception may vary based on people's contexts, experiences, and culture. For example, individuals with a collectivist cultural background tend to pay greater attention to peripheral or background objects in a scene [1]. In Figure 1(a), when seeing the picture of a person throwing a frisbee (the picture at the top-right), some people may first notice the frisbee while others may notice subtleties like the baseball caps or the building in the background.

Second, in the internal perception space, individuals then recognize and understand the visual elements they have attended to. There could also be cognitive variability at this level. People may interpret what they attend to differently based on prior experiences and current framing; visual illusions are often cited to demonstrate this variability [3].

Third, these perceptions may trigger concepts in the space of associative memory, followed by spreading activation of interconnected concepts. Again, people differ in how concepts are organized and stored in their memory due to experiences, socialization and education. In Figure 1(a), thinking of "baseball cap" by viewing the picture at the top left may lead the person to think of "sport" via the associative link between concepts, even though the picture at the top left has nothing to do with sports. (Others of us may, unfortunately, think "bald".)

At the bottom of the Figure 1(a), verbalization feeds into the cognitive process as well. Words from the chat may activate concepts; combining the spreading activation from both pictures and words may lead to new ideas being generated. This may in turn lead to the activation of new concepts, the expression of new ideas, and the selection of new pictures to continue the cycle of idea generation—reversing the vicious circle described earlier.

Collaborative Idea Expansion

The power of the cognitive processes may be fully unleashed when we connect multiple individuals with both the picture and verbal communication spaces because this leverages interpersonal variability. Figure 1(b) shows the scenario of connecting two people in a social creativity system. By using the concepts currently present in the chat to select pictures, the agent can take advantage of the differences in perception and associative memory between people to find pictures that are both related to currently activated concepts (as reflected by the words people type). That may lead to divergent chains of spreading activation in each participant, reducing the chance that the conversation will become fixated and increasing the chance of new idea generation. In short, the system helps people to *see* what other people have *said* in new ways and to expand their ideas using multiple pathways.

IMPLEMENTATION AND EVALUATION

We implemented a prototype of IdeaExpander in order to evaluate the general approach of using pictures to stimulate creativity. The implementation uses a combination of machine learning, information retrieval, and wizard-of-oz techniques. The wizard of oz aspects draw on a prior experiment in which participants brainstormed in a chatroom about the benefits and drawbacks of having an extra eye or thumb [9].

Figure 2 shows both a screenshot and the agent's high-level architecture. Participants use a chat window on the right side of the window, while the agent displays pictures it chooses based on the conversation on the left. The architecture has three main components: a language processor, a picture retriever, and an image chooser. We briefly discuss each in turn.

Language processor. IdeaExpander monitors the chat to find keywords that it takes to be related to the set of currently activated concepts among partners in the conversation. Because brainstorming conversations include both on-task and off-task remarks, IdeaExpander uses a SVM classification model to determine whether a remark contains an idea or not based on 5,391 labeled turns from the experiment in [9], achieving a classification reliability of Kappa .61 (80% accuracy).

Picture retriever. IdeaExpander uses keywords drawn from remarks classified as containing ideas to retrieve candidate pictures to show. The end goal is to use datasets such as Google Images or Flickr that contain well-labeled images; since these databases are not yet well-labeled, we created our own tailored for these tasks. In [9], analysis resulted in a coding scheme containing 110 (thumb) and 118 (eye) idea categories. We collected 60 pictures for each task from Flickr; two people then coded each picture with the idea categories that pertained to the picture (Krippendorff's alpha=.5). We then labeled each picture with the tags it already had from Flickr and the words contained in the codebook descriptions of the idea categories.

The agent matches conversational turns it classifies as containing ideas against the keywords in the database using TF-IDF in order to retrieve a *relevant set* of pictures. For simplicity, it currently matches each turn individually. Exploring the design space for how much and how strongly to consider previous turns would be interesting future work.

Picture chooser. The agent then attempts to choose pictures that will optimize cognitive stimulation. In the general case, we think this would involve choosing pictures associated with concepts that are near both participants' currently activated concepts and that lead to new ideas. This is non-trivial in general (see [7]); here, we compute a utility score that prefers pictures that may stimulate many ideas and ideas that are less likely to be generated.

We used the dataset from [9] to estimate the probability that a brainstorming group would generate each idea category, and weighed each idea *i* as log(1/probability of idea *i*). The utility score for a picture is the sum of weighted scores of the ideas coded as pertaining to it. The agent selects the picture from the relevant set with the highest utility score that has not yet been shown and updates the picture space with a new picture every three seconds.

Evaluation

We recruited 16 participants, forming eight brainstorming pairs. Each pair performed both the thumb and eye tasks, using IdeaExpander for one task and a standard chatroom for the other, generating a total of 32 observations. The order of tasks and tool use was counterbalanced. Pairs worked 14 minutes for each task. Residual analysis showed that one of the 32 observations was an outlier, so it is not included in the statistics below.

We first compared ideation productivity across conditions. Two people independently coded the chat using the coding scheme from the prior experiment (Kappa=.66). Categories were only counted as unique ideas once per group. A mixed model ANOVA that accounts for the dependency between group members showed that even with the small sample size, individuals appear to generate more ideas when working with IdeaExpander (14.3) than without (12.0) (F[1,13]=2.88, $p \leq 0.1$). That is, IdeaExpander helped people think of 2.3 more ideas in a short brainstorming session. Quantity may breed also quality and originality of ideas. People generated more "rare" ideas (those with rates of occurrence lower than 1%) with IdeaExpander (4.3) than without it (3.5) (F[1,13]=2.36, $p \leq 0.1$).

We also looked at people's attitudes toward IdeaExpander. On a post-experiment survey, 13 of 16 participants said the pictures were helpful (6) or sometimes helpful (7). Some informally praised the system; one volunteered that the pictures were helpful for him to think smoothly; another was excited about IdeaExpander's interaction model.

CONCLUSION

The evaluation demonstrates the value of IdeaExpander as a tool to support group brainstorming. IdeaExpander itself is a proof-of-concept. A fully functional system would require work in a number of areas, including developing effective representations of active concepts in the group and in each member, creating larger databases of labeled picture information, and creating algorithms that more effectively use associative networks of concepts, perhaps drawing on ideas from work around concept maps [6] or general tools for discovering associations between ideas (e.g., [7]). IdeaExpander could also use different media (sounds, videos, text clips), or allow participants to contribute keywords directly to the agent as a way of sidestepping social inhibitions about expressing ideas in the conversation itself. Our results suggest it is worth exploring these questions in support of group creativity.

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