

Trains of thought on the tabletop: Visualizing association of ideas improves creativity

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Abstract

According to the SIAM theory (Search for Ideas in Associative Memory), ideas in a brainstorming session do not come one by one but rather in “Trains of Thought”, which are rapid accumulations of semantically related ideas. In order to visualize these trains of thought, we developed a brainwriting tabletop interface enabling users to link successive ideas together by means of graphical ropes. To test the effectiveness of this device, forty-eight participants (in groups of four) brainstormed for twenty minutes on the tabletop in one of two conditions: either with the Train-of-Thought interface (with graphical ropes), or without the ropes (Control condition). The results show that visualizing the associations between ideas enabled the participants to produce longer trains of thought. We also assessed originality by collecting the unique ideas in the whole corpus of ideas produced by the different groups, and observed that the Train-of-Thought condition produced more original ideas than the control one. One interpretation of this finding is that visualizing trains of thought increases cognitive stimulation, i.e. improves creativity by making others’ ideas more intelligible to the brainstorming partners, with comparison to the classical visualization of ideas as independent labels.

Keywords

Train of thought, brainstorming, interactive tabletop system, SIAM theory

1. Introduction

Tabletop systems are multi-user horizontal interfaces for interactive shared displays. They implement around-the-table interaction metaphors allowing co-located collaboration and face-to-face conversation in a social setting [1]. Tabletop devices have been developed for various application fields such as games, photo browsing, map exploration, planning tasks, classification tasks, interactive exhibit medium for museums, drawing, etc. [2,1]. Because tabletop systems provide sharing and visualization facilities (situation awareness) while emphasizing the social nature of collaboration (group awareness), they can also be expected to meet the requirements of creative problem solving tasks. Indeed, creativity-supporting tools are another popular kind of application for tabletops [3-8].

One of the most classical creative problem solving methods is group brainstorming [9]. This is a collective idea generation technique which enables the group to benefit from many collective phenomena that promote creativity, but also suffers from several failings. Examples of positive effects associated to group brainstorming include *cognitive stimulation*: the exposure to other participants’ ideas enhances idea generation [10-12]. *Social comparison* is another benefit of group brainstorming, since the possibility of comparing one’s own performance to the others’ was also shown to increase creative performance [13,10,14-16]. However, a major shortcoming of “oral” brainstorming is the necessity of managing speech turns: each participant has to wait for his turn to give an idea, and only one idea can be given within a turn. This severely interferes with the idea generation process and results in *production blocking* [17,15]. One simple solution is to use the written instead of the oral channel to record the ideas, which can be referred to as brainwriting [18,19]. In this case, participants silently share written ideas, for example on sticky notes. Finally, another key issue in brainstorming is *social loafing* [20-23]: in brainstorming groups, some participants tend to under-contribute with comparison to a situation where they would brainstorm alone.

Tabletop devices are particularly well suited for creativity because they support both cognitive stimulation (situation awareness) and social comparison (group awareness). Moreover, they have the potential to overcome the aforementioned limitations of group brainstorming. They generally implement brainwriting interfaces, in order to avoid production blocking. They are also likely to decrease social loafing in at least two ways. Firstly, the “around-the-table” form factor increases equity of collaboration [7]. Equity corresponds to the inverse of social loafing and correlates to the Collective Intelligence of a group, a factor that explains the group’s performance on a wide variety of tasks [24]. Furthermore, the attractiveness of the tabletop device increases extrinsic motivation to engage in the task [7], which is also a moderating factor of social loafing [25,26].

In the present study, our goal is to further improve idea generation with comparison to existing tabletop brainwriting tools. To this end, we implemented and tested a new interface based on the SIAM theory – Search for Ideas in Associative Memory [27-29], as explained below.

2. Theoretical background

SIAM is an extension of the SAM theory (Search of Associative Memory [30]) and was created to account for the impact of production blocking on idea generation. SIAM theory proposes that the exposure to other group members’ ideas improves individual’s creative production; the quantity of ideas, but also the content of the ideas [12,31]. This theory refers to the two memory systems known as working memory (WM) and long-term memory (LTM). The first is a limited-capacity memory where conscious operations are performed, and the second is an unlimited-capacity memory where previous experiences are stored, and most important for our topic, the LTM is partitioned into “images” (not necessarily visual or spatial), which are interconnected and semantically related (associative memory). So, when a person is performing a brainstorming (or brainwriting) task, the search in LTM results in an image activation which is temporarily placed in the WM. When an image has been activated, its semantic relations in LTM can be used to generate other ideas [32]. In this case, as successive ideas generated are semantically related, the SIAM theory proposes the concept of “train of thought”, which is a rapid accumulation of semantically related ideas [29]. During a brainstorming session, ideas are supposed to come in this form rather than one by one. When a train of thought is over, it takes some time to find a new idea: a new train of thought can be generated through the self-activation of a new semantic category or through stimulation from another participant’s idea. But the same kind of process is involved in either case, with the activation of semantically related images in memory.

In this paper we want to test whether visualizing trains of thought helps idea generation and improves group creativity (number and originality of ideas). We hypothesize that visualizing the semantic links between successive ideas will increase the length of trains of thought, by allowing participants not to lose the thread of their thought, and promote going further in idea generation. We also propose that this visualization will help participants better understand other participants’ ideas by enabling them to track their semantic associations, and so improve the stimulation mechanism.

In order to test this hypothesis, we compared the creative performance of groups using a “train of thought” tabletop interface (offering the possibility to visualize association of ideas) and groups using a tabletop brainwriting interface with no link between ideas that are successively generated.

3. Implementation

To operationalize these two conditions (Train-of-thought and Control), we developed two Graphical User Interfaces (GUIs) in JAVA for horizontal shared tabletop display. We used the DiamondSpin toolkit [33] to take advantage of the existing tabletop specific features (menu bars on each side of the table, automatic orientation of graphical elements, concurrent multi-user input). We also used the new multi-keyboard bindings to provide our users with the benefits of Bluetooth keyboards over virtual keyboards (typing speed and low typing errors, especially for users with few/no experience of tablets). Both prototypes display a 1-line text field on each side of the table (where the text of each participant is displayed as being typed). At startup, the 4 text fields display 4 different pin codes. If a user takes one of the Bluetooth keyboards and types the pin code in front of him/her, this keyboard is associated with the Diamondspin ID of this user. Each individual text field is augmented with a movable grey area so that users can move it to correspond to where they position their Bluetooth keyboard. On the left of each text field a draggable menu bar recalls the topic of the session. Finally a single “File” menu is displayed in a corner of the GUI (open, save, clean, etc.) to be used by the experimenter. The rest of the GUI differs in the Train-of-thought and Control conditions.

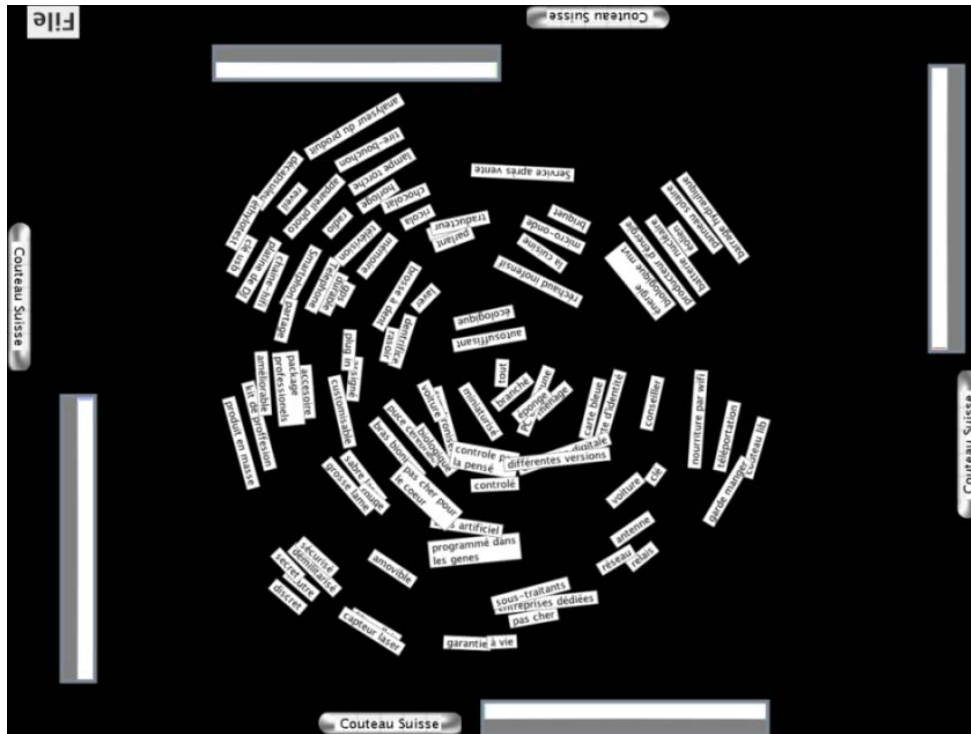


Figure2: The control interface: Ideas are written on independent labels.

4. Experimental protocol

Participants

12 groups of four participants (48 users in total) were involved in the experiment. All of them were students or staff members from our school, and they were not familiar with each other. They were 42 men and 6 women, aged 18-60 years (mean = 21 SD = 5.94). The participants were not paid for their participation.

Material

We used a 107-cm Circle Twelve DiamondTouch device [34] with a 1400x1050 projected display. Participants worked in groups of four seated around the tabletop, interacting with finger-input on the display and typing their ideas by means of wireless keyboards (Figure 3).



Figure 3: The experimental setup.

Procedure

Each session began with a presentation of the tabletop system and the brainwriting method. The participants were invited to familiarize themselves with the interactive tabletop and have a practice session. After that, the goal of the session was presented: the participants had to imagine the “Swiss Army knife” (a multi-function multi-tool pocket knife) of the future. They were then explained the four brainstorming rules [9]: Focus on quantity, Withhold criticism, Welcome unusual ideas, Combine and improve ideas.

The type of brainwriting interface was a between-subject variable: half of the groups (control groups) had to write their ideas on independent virtual labels (one idea per label, see Figure2). In the other half of the groups (Train-of-thought groups), participants were invited to write their ideas on similar virtual labels, which were linked successively along a graphical rope. When the participants decided that they had finished an association of ideas, they could cut the rope and were then ready to start a new one. All the participants were free to examine all the ideas displayed on the table, and add new ideas or new pieces of rope to those that had been generated by their partners (Figure1).

In both conditions participants were allowed to manipulate the ideas (or the ropes) from anywhere in the interface, and place them wherever they wanted. They were encouraged to react on all these ideas in order to generate as many ideas as possible. The experimenter played the role of session facilitator. In both condition, participants brainstormed for 20 min on what could be the Swiss Army knife of the future.

At the end of the 20 minutes, they had to fill out a questionnaire to assess how they perceived the device, the interface and their performance (see below the list of items). Finally they were invited to give us their opinion about the experiment.

Data collection and analysis

We used the same variables as Nijstad *et al.* [28] in order to characterize idea generation:

- Number of ideas generated by each participant (N), after cleaning the corpus from incomprehensible notes and from duplicates in each user’s production.

- Length of trains of thought for each participant ($N/(N-R)$), with R the number of ideas from the same semantic category: each idea was manually classified as “same” vs. “new” category with regard to the preceding idea. This analysis was based on log files only, with timecodes and ideas of all participants. To ensure a similar analysis to the control condition, we disregarded the graphical ropes that had been inserted by users in the Train-of-thought condition.
- Number of trains of thought for each participant ($N-R$).
- Diversity (D), i.e. the number of semantic categories in each participant’s production.
- Within-category fluency (N/D).

We added to this set of variables another variable to assess the originality of ideas (O). Although originality was not examined by Nijstad, it is considered as the most widely acknowledged requisite for creativity [35]. We assessed it by collecting the number of unique ideas [36] with regard to all the ideas proposed by all the groups.

We also analyzed the following subjective data (ratings on 7-point Likert scales): suitability of the tablet device for this creative task, suitability of the interface, ease of use of the interface, ease of entering ideas, ease of reading other participants’ ideas, self-assessment of the quantity of ideas generated, self-assessment of the quality of ideas, self-assessment of the degree of collaboration, usefulness of others’ ideas to be creative, enjoyability of the session, fun, effectiveness of the session.

5. Results

The whole corpus contained 1025 ideas. After cleaning incomprehensible notes and duplicates in each participant’s production, we retained 998 ideas, which corresponds to 20.8 ideas per participant. In this corpus, semantic categories were manually annotated by a single judge. In order to test the reliability of this classification, a second independent judge performed the same annotation on a sample of the corpus. Inter-judge agreement on this sample amounted to $Kappa=0.652$. We followed the same procedure to assess the reliability of the selection of unique ideas. Uniqueness of ideas was decided with regard to the whole corpus, forming a database of answers to the Swiss Army knife problem. In this corpus a single judge identified the ideas appearing only once and considered them as unique ideas. A second independent judge analyzed a sample of the corpus and inter-judge agreement amounted to $Kappa=0.631$. The judges agreed on a set of 96 unique ideas (i.e. 9.62% of the corpus), examples of which being presented in Table 1.

Examples of unique ideas: <i>A knife that would...</i>
Be a jewel
Cut everything but human skin
Cut the hair by itself
Detect my car in the parking lot
Detect rifts
Identify plants
Include a breathalyzer
Include a protection bubble for the rain
Include a radar for visually disabled people
Record what I eat during the day

Table 1: Examples of unique ideas (extracted from the set of 96 ideas). Unique ideas are those that appear only once in the whole corpus of 998 ideas (aggregation of all groups’ productions).

The differences between Control and Train-of-thought conditions were analyzed by means of t-tests (Table 2). Only three variables showed significant differences between conditions. The Train-of-thought condition yielded significantly longer trains of thought ($t(46)=-2.35$; $p=0.023$) and many more original ideas ($t(10)=-3.676$; $p=0.004$). However, the Control interface was judged as significantly easier to use than the Train-of-thought interface ($t(46)=2.38$; $p=0.022$). The other variables showed no significant difference. In particular, the Train-of-thought interface did not result in more ideas, more diversity, or more fluency, and participants did not feel more effective.

<i>Variable</i>	<i>Condition</i>	<i>Mean</i>	<i>Standard Deviation</i>	<i>t-test</i>
Quantity of ideas (N)	Control	20.33	12.994	t(46)=-.336; NS
	Train of thought	21.33	6.644	
Length of trains of thought (N/(N-R))	Control	1.26	.1981	t(46)=-2.35; p=0.023
	Train of thought	1.497	.4574	
Number of trains of thought (N-R)	Control	15.88	9.181	t(46)=.342; NS
	Train of thought	15.13	5.605	
Diversity (D)	Control	9.13	3.055	t(46)=0; NS
	Train of thought	9.13	2.675	
Within-category fluency (N/D)	Control	2.11	.8436	t(46)=-1.44; NS
	Train of thought	2.46	.8381	
Number of original ideas (O)	Control	4.67	2.944	t(10)=-3.676; p=0.004
	Train of thought	11.33	3.327	
Suitability of the device	Control	5.54	1.215	t(46)=-.957; NS
	Train of thought	5.83	.868	
Suitability of the interface	Control	5.54	.884	t(46)=-.834; NS
	Train of thought	5.75	.847	
Ease of use of the interface	Control	6.42	.776	t(46)=2.38; p=0.022
	Train of thought	5.83	.917	
Ease of entering ideas	Control	6.63	.576	t(46)=.202; NS
	Train of thought	6.58	.830	
Ease of reading ideas	Control	5.08	1.381	t(46)=.957; NS
	Train of thought	4.71	1.334	
Self-assessed quantity of ideas	Control	4.438	1.262	t(46)=-.824; NS
	Train of thought	4.708	.9991	
Self-assessed quality of ideas	Control	4.42	.830	t(46)=.708; NS
	Train of thought	4.21	1.179	
Self-assessed collaboration	Control	4.71	1.197	t(46)=.708; NS
	Train of thought	4.46	1.250	
Usefulness of others' ideas	Control	5.33	1.373	t(46)=-1.644; NS
	Train of thought	5.88	.850	
Enjoyability	Control	6.04	.955	t(46)=.153; NS
	Train of thought	6.00	.933	
Fun	Control	6.00	.978	t(46)=.39; NS
	Train of thought	5.88	1.227	
Effectiveness	Control	5.00	1.651	t(46)=.639; NS
	Train of thought	4.74	1.054	

*Table 2: Detailed results: mean, standard deviation and t-test for each variable.
Bold font indicates significant results.*

6. Discussion

The most striking result of our study concerns the number of original (unique) ideas. We observed a huge difference between the control and the Train-of-thought condition: on average, participants generated more than twice as many unique ideas in the Train-of-thought condition! This result suggests that visualizing the association of ideas enabled the participants to go further in the association and therefore reach more original ideas. In the associative creativity theory [32], the semantic distance in association of ideas is considered as favoring creativity. The simple graphical artifact we used (a rope between labels) proved very effective in increasing originality. To obtain this result, we collected unique, i.e. statistically rare ideas [36]. To confirm or complement this result, we could perform new analyses on the corpus, for example make a sample of potential users (of Swiss Army knives) rate the originality and usefulness of each idea, in order to decide whether the Train-of-thought condition yielded more original or useful ideas (from the users' viewpoint).

As hypothesized, the Train-of-thought interface with its ability to track associations between ideas during the brainwriting session, enabled the participants to produce longer trains of thought. The difference in length was significant although it seems minor (1.5 vs. 1.3 ideas, see Table 2) and corresponds to very short trains of

thought. In contrast, the look of the interface at the end of the session (Figures 1 and 3) shows quite long ropes of ideas. Here it should be reminded that only ideas that were *successively generated by the same user and in the same semantic category* can be considered a train of thought [27-29]. For example, we observed in our experiment the following succession of ideas: “Magnifying glass – Sharpener – Lamp – Isolated blade”, which was represented on a single thread by the user. However, it was recorded as a succession of four trains of thought of only one idea each because it alternates two semantic categories (stationery and tools). It seems that this participant was actually following two associations of ideas at the same time, which is contradictory to the principle that only one image should be activated in working memory at a time [29]. Likewise, the following ideas “Clothesline – Dental floss” were successively generated by the same user, and added to different ropes. Consistently, they were classified in our analysis in different semantic categories, and therefore in different trains of thought. However, they may actually come from the same association of ideas, because there is a clear formal and lexical (in French: “Fil à linge – Fil dentaire”) similarity between them. There are many examples of this kind, emphasizing the limitations of our analysis of idea generation mechanisms. In this study we chose to follow Nijstad’s [28] analysis method, in order to be consistent with the SIAM theoretical framework, but these examples call for new and more accurate analysis methods to better account for the effects of our Train-of-thought interface on idea generation.

The final display of ropes on our interface shows associations of ideas that were completed in one or several steps by a single participant, and also associations of ideas that were collectively completed: one participant generated a piece of rope, another one extended it, etc. The form of the interface encouraged the participants to do so and this became a real strategy for some users: for example we observed some of them thinking in a loud voice “how can we extend this rope?” This kind of strategy as well as the whole phenomenon of stimulation (using others’ ideas to find new ideas) is not accounted for in the variables we collected. Moreover, even if we want to, we cannot measure this phenomenon in the control condition. When there is no visual link between ideas, how can we detect where the stimulation comes from? Which idea the user drew inspiration from at a particular moment? Such implicit activation mechanisms cannot be captured in this experiment.

Finally the third significant result we obtained concerned the ease of use of the interface. Our Train-of-thought interface proved to be more difficult to use than the Control interface. This may be due to the differences in functionality between the two interfaces. However, it also prompts us to improve our design. Some of our users suggested improving the way to move ropes (e.g. catch a rope by the labels and not necessarily by the knots) and to tie them together (e.g. tie existing ropes together, connect knots), and automatically arranging the threads so that all the ideas are always readable (no overlap).

7. Conclusion

By simply providing graphical ropes to link together successive ideas, we managed to greatly increase the number of original ideas in a group brainwriting session. Graphical ropes may have helped each participant to go further in his/her own associations of ideas (i.e. produce longer trains of thought), and they may also have helped brainwriting partners to gain higher stimulation from sharing ideas together. We believe that this second effect was a key factor to increase originality, even if we cannot confirm it with the data collected in this study. Further experiments will be necessary to better understand the role of graphical ropes in cognitive stimulation.

Our initial intuition of implementing a brainwriting tabletop interface based on the principles of the SIAM theory proved fruitful, even if our results do not exactly match the predictions of the theory. In particular, we believe that the concept of train of thought should not be limited to the initial association of ideas occurring in one’s mind, and that a train of thought can be extended by the same or by another participant. Also, can several trains of thought be concurrently activated in one’s mind? Future work should include several refinements of the protocol to answer such questions, as well as several refinements of the analysis methods to better account for the complex mechanisms of associative memory activation and cognitive stimulation.

Other limitations of the present study should also be addressed in future works. The population we observed was composed of students and university staff, and we used quite an artificial brainwriting subject (Swiss Army knife of the future). It would be interesting to replicate this study with groups of co-workers such as design teams on real design problems, or ad hoc creative groups with real expectations regarding the outcome of the session. We believe that the effects we observed may even be emphasized in a more realistic context. Therefore, despite the limitations of our study, we think that it provided new insight on brainwriting effectiveness, and hope it will stimulate further research about tabletop-supported creativity.

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9. References

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