Computer-supported creativity: Evaluation of a tabletop mind-map application

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Abstract. The aim of this study is to investigate the usability and usefulness of interactive tabletop technologies to support group creativity. We implemented a tabletop interface enabling groups of 4 participants to build mind-maps (a tool for associative thinking). With 24 users in a within-group design, we compared its use to traditional paper-and-pencil mind-mapping sessions. The results showed no difference in idea production, but the tabletop condition significantly improved both subjective and collaborative dimensions, especially by leading to better-balanced contributions from the group members.

Keywords: Creativity, Mind-map, Tabletop device.

1 Creativity in industrial applications

Creativity is a high-level cognitive process which has given rise to researches in various fields such as Psychology [4, 16], Engineering [7, 9] or Human-Computer Interaction [3, 6, 14, 15]. Creativity applies to artistic work (e.g. fine arts, literature, architecture, music), educative domain (e.g. early-learning and playing activities), scientific skills (e.g. problem resolution, discoveries, epistemological breakthroughs), and industrial applications (e.g. creation of product functions, stylistic design of artifacts).

In this paper we consider creativity in industrial applications, for example when some people design a product with new innovative functions (e.g. a mobile phone including a positioning system) or search some applications to a new technology (e.g. portable MP3 players). Understanding and supporting this kind of creativity is not only an interesting research challenge: it also bears a strong potential for enhancing industrial innovation and market opportunities.

2 Enhancing creativity

To improve creativity, a wide-spread practice in companies is the group brainstorming. Although creativity fundamentally remains an individual capacity, it proves to be influenced by the subject's environment: in this respect, collective creativity phenomena are often observed when group emulation improves the expression of one's own creative potential. This is especially true for industrial creativity which can benefit from multiple, or even multidisciplinary viewpoints.

To further improve these collective creativity sessions, methodological toolkits [7, 9] have been formalized to structure the reflection and manage groups' dynamics. Consulting services specialized in creative problem solving also appeared to help companies conduct creativity sessions and apply these methodologies.

Moreover, computer applications have been developed to support industrial creativity[1]. According to Shneiderman [14], the existing software solutions can be categorized into three approaches: inspirational tools (e.g. favoring visualization, free association, or sources of inspiration), structural tools (e.g. databases, simulations, methodical techniques of reasoning), and situational tools (e.g. based on the social context, enabling peer-consultation, or dissemination). Lubart [8] adopted a classification grounded on the role played by the computer in the creative process: systems assisting the user in the management of creative projects (computer as nanny), those supporting communication and collaboration within a team (computer as pen-pal), systems implementing creativity enhancement techniques (computer as coach) and those contributing to the idea production (computer as colleague).

In this context, our goal is to investigate the capacity of a tabletop computer (as a physical device and as a digital interface) to support collaborative creativity related to industrial issues.

3 Tabletop systems

Fig. 1. Example of a tabletop system using MERL DiamondTouch device [5].

Tabletop systems (see Fig. 1) 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 [12, 13].

[1] For example Goldfire Innovator (www.invention-machine.com) or ThoughtOffice (www.ideacenter.com).

Tabletop systems are used in various application contexts such as games, photo browsing, map exploration, planning tasks, classification tasks, interactive exhibit medium for museums, drawing, etc. [11]. Such systems being likely to favor collaboration by providing around-the-table visualization facilities, they could be thought of for supporting creativity sessions: in this respect they would fall into both inspirational and situational creativity tools [14] or play pen-pal and coach roles [8] in the creative process. Indeed, some tabletop systems were previously considered for supporting creativity [17, 18] but their actual benefits were not experimentally measured. To assess the usability and usefulness of tabletops in the context of creativity sessions, we believe that it is necessary to compare their use with a control condition relying on traditional paper-and-pencil tools. In the following section, we introduce a creativity application we have developed for tabletop display in order to conduct such an experiment.

4 Our tabletop mind-map application

4.1 Mind-maps as a collective creativity tool

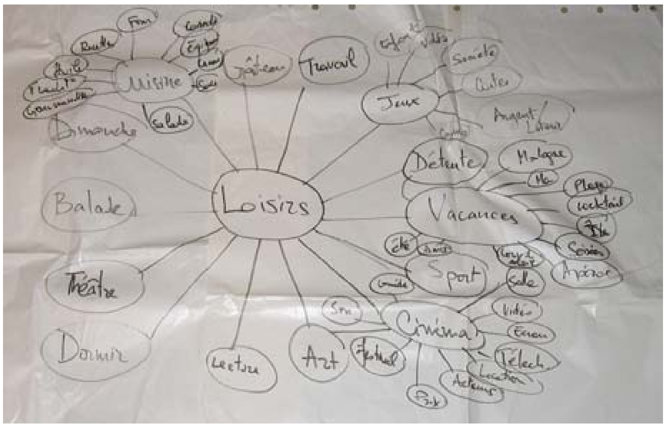

Fig. 2. Example mind-map.

In general, creativity methodological framework [7] support a two-step process: first, diverging by producing a vast number of ideas, then converging by selecting a few of them to be further developed. Mind-maps [2] are used in the diverging step. The mind-map principle is based on associative logics and is used for defining the problem to address. The field to explore is written in a central box and the participants express their free associations to this concept. Those ideas are written in new boxes placed as a crown around the central concept (see Fig. 2). A second association level is then built from the primary ideas, etc. Because the second level of association is not directly related to the initial problem, new-original research directions can appear and the realms of possibility grow. Mind-mapping can be performed individually or in a group session. In the latter case, the session has to be managed by an animator whose role is to coordinate speech turns and ensure that the group agrees on every idea. Many software solutions[2] for desktop computers have been developed to support mind-mapping, but none is adapted to tabletop interaction. This is why we implemented our own tool.

4.2 Implementation

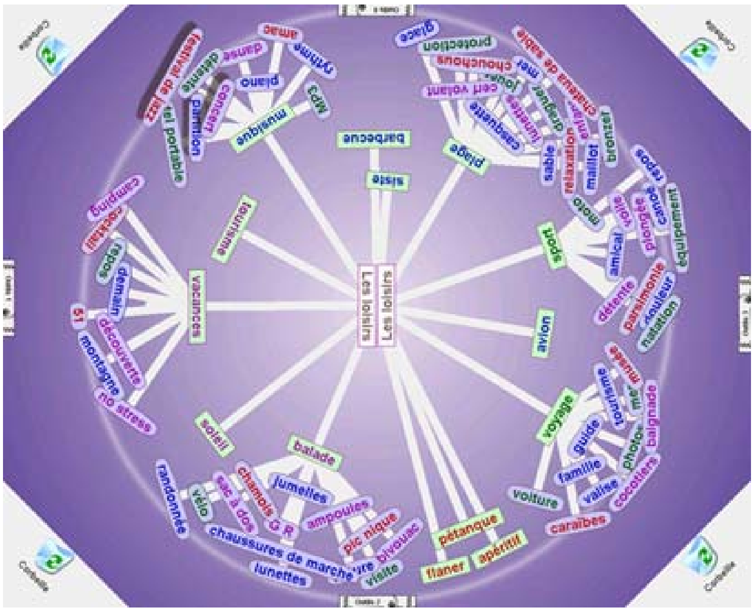

Fig. 3. Example mind-map created with our tabletop application.

Implementation of Tabletop Mind-Maps (TMM, see Fig. 3) was conducted with the DiamondSpin toolkit [13]. TMM was also based on our previous experience with a hierarchy view, namely the Personal Digital Historian (PDH) application [12], which is dedicated to organizing family pictures according to a hierarchy of people and concepts present in the pictures.

A TMM session starts with a root label forced to be in center. The root displays the field to explore, which is important to keep in mind, so we duplicated the label along a symmetry axis to have it more readable from every point of view around the table.

The mind-map is then built top-down when users create new nodes with double-tap-and-drop interaction. This concatenation of double-tap and drag-and-drop appeared to be natural and easy to perform with direct manipulation. The double-tap creates a new node in the sub-hierarchy of the tapped node, while the drag-and-drop specifies the new node position. The background color of the node represents its level in the hierarchy (green for 1st level, blue for 2nd level…).

[2] A complete list of mind-mapping software is available at www.mind-mapping.org, the market leader being MindManager (www.mindjet.com).

TMM nodes are editable. The choice of a label being a collaborative activity in mind-mapping, this aspect had to be reproduced in TMM: we chose to allow text input only from a single source, i.e. a physical wireless keyboard with a particular focus management. Indeed, in a tabletop system there can be more than one focused or selected element, as the users interact seamlessly together or in parallel. We made the keyboard focus persistent until the Enter key is pressed. While the text is being keyed, users can create new nodes or select other ones (e.g. to check for possible redundant node's name) without interfering with the edition. The font color of the node represents the user who created it.

Nodes of the hierarchy are freely relocatable on the table. The nodes of a sub-hierarchy will also follow their parent node when the latter is moved on. The orientation of the nodes is adjusted online while they are being moved on so that the text is always oriented outwards to be readable by the nearest user. Moreover, users can rotate the whole display if they want to change the view without changing the arrangement of the hierarchy.

Finally, we introduced a means of creating a temporary view of a sub-hierarchy. A given node becomes the new central root, all the items outside of its sub-hierarchy being temporarily hidden.

5 Experimental study

This experiment was designed to evaluate the use of a tabletop interactive application for mind-mapping by comparing it with a control paper-and-pencil condition.

5.1 Method

Participants. 6 groups of 4 participants took part in the experiment. Each group included students, professors and/or employees. We excluded groups only composed of students in order to avoid too much familiarity among participants and simulate more realistic conditions of creativity sessions. Overall, users' age ranged from 20 to 52 years old (mean = 28.7; SD = 7.9) and each group was composed of 2 male and 2 female participants.

Materials. For the tabletop condition, we used MERL DiamondTouch [5]: the participants were seated around the table with the experimenter sitting aside on a highchair. The participants interacted on TMM display with finger-input to create, edit or move the mind-map items. The experimenter typed down the content of the nodes using the wireless keyboard.

In the control condition the participants were seated in front of a paperboard with the experimenter standing beside it. The experimenter used a marker pen to build the mind-map and write down its content according to the participants' indications.

Procedure. Each group had to build 2 mind-maps on different topics: 1 in the tabletop condition and 1 in the control condition. The topics were related to the sectors of "Media" and "Leisure": such topics simulate potential reflection for e.g. companies trying to find a way to diversify, searching an application for a new technology or trying to find new markets. These 2 topics were chosen so as to be equivalent in level of abstraction and width of scope. The order of conditions and the assignment of topics were counterbalanced across the whole sample (see Table 1).

Table 1. Counterbalancement of conditions: For each group (A to F), this table defines the order of the 2 conditions (Tabletop and Control) and the topic addressed in each case (Media and Leisure sectors).

Group ID	First mind-map	Second mind-map
A	Tabletop: *Media*	Control: *Leisure*
B	Tabletop: *Leisure*	Control: *Media*
C	Tabletop: *Media*	Control: *Leisure*
D	Control: *Media*	Tabletop: *Leisure*
E	Control: *Leisure*	Tabletop: *Media*
F	Control: *Media*	Tabletop: *Leisure*

To conduct the session, the experimenter first asks the general question "What does *leisure* (resp. *media*) make you think of?" The participants freely suggest some ideas and concepts associated to the target sector, and the experimenter writes down the ideas the group agrees on. Once the first level of the mind-map is completed, the same process is repeated for the second level by focusing on first-level ideas one by one ("What does *xxx* make you think of?"). In this experiment the mind-maps were limited to 2 levels and the time to build them to 10 minutes. The differences between tabletop and control conditions in building the mind-maps are summarized in Table 2.

Table 2. Differences between tabletop and control conditions in the process of mind-mapping.

Factor	Description
Spatial position of participants	Around the table vs. in front of the paperboard
Creation of new boxes	By the participants in the tabletop condition vs. by the experimenter in the control condition
Modification / suppression of a box	Allowed in tabletop but not in control condition
Spatial arrangement of items	Online modifications allowed in tabletop but not in control condition
Rotation of the mind-map	Allowed in tabletop but not in control condition
Focus on a first-level idea	Explicit in tabletop (making the rest of the mind-map disappear) vs. implicit in control condition (whole map always displayed)

The tabletop condition was preceded by a familiarization phase for demonstrating the table's functionalities to the participants. Both tabletop and control conditions were then video-recorded. At the end of the experiment, users had to fill in a questionnaire to assess the following dimensions: efficiency, usability, usefulness of the tabletop system, satisfaction, and comparison with the control condition. Users had to quantify their impressions on 7-point scales and were particularly prompted to complete with free qualitative comments. The whole experiment lasted about 1 hour for each group.

5.2 Data analysis

Inferential analyses were performed by means of ANOVAs using SPSS software. Three dimensions were investigated: the performance in mind-mapping, the subjective experience of users, and the collaborative behaviors.

Performance. We chose to assess the performance dimension from the exhaustiveness of the outcome. As we lack absolute standards to evaluate a mind-map in itself, we decided to aggregate the mind-maps of the 6 groups for the same topic and take this as a reference to be compared to each mind-map. We rated the exhaustiveness of the mind-maps by considering both the total number of ideas and the number of categories of ideas in comparison to the reference.

Subjective experience. This dimension was computed from the questionnaire ratings. The analysis processed on these data also accounted for users' gender and category (student, professor or employee).

Collaboration. The participants' collaborative behaviors were annotated from the video-recordings of the sessions. We collected the following behaviors: assertions (e.g. giving an idea), information requests, action requests, answers to questions, expression of opinions, communicative gestures related to the task, and off-task talks. The "communicative gestures" variable includes e.g. pointing to the map, interrupting s.o. or requesting the speech turn by a gesture, which can be observed in both conditions. In the tabletop condition, it also includes gesture-inputs on the table, with the exclusion of creation / edition / suppression actions which we did not consider as communicative gestures.

We first analyzed the raw behavioral data for each participant, and then we converted them into percentages in order to assess the respective contribution of each participant in the group. Such an index finally enabled us to compute the difference between the actual collaboration pattern of each group and a theoretical perfectly-balanced pattern (each one of the 4 participants would contribute 25%).

5.3 Results

Performance. No significant difference appeared between tabletop and control conditions on our index of exhaustiveness of mind-maps ($F(1/5) = 0.92$, NS).

Subjective experience. There was no significant effect of the condition (tabletop vs. control) on easiness ($F(1/20) < 0.1$, NS) and efficiency ($F(1/20) = 1.02$, NS) of mind-map building. However, the tabletop was rated as significantly more pleasant to use ($F(1/20) = 10.43$, $p = 0.004$), enabling a more pleasant communication between participants (F(1/20) = 5.01, p = 0.037), more efficient group work (F(1/20) = 3.56, p = 0.074) and more pleasant group work (F(1/20) = 4.23, p = 0.053) – see Fig. 4. Users' gender and category had no influence on any of the previous results.

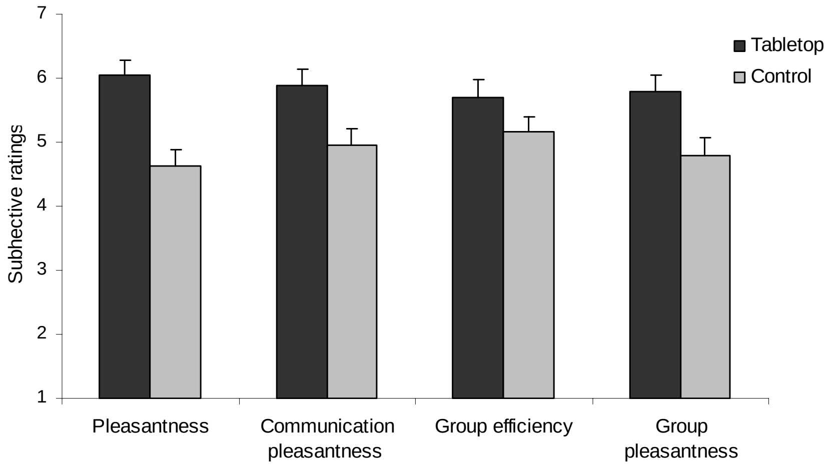

Fig. 4. Subjective ratings of participants for the tabletop and control conditions.

Collaboration. The variables "expression of opinion" and "off-task talk" comprised too many missing values to be analyzed. The other raw behavioral data showed no significant difference in the absolute number of any of the variables, except for the communicative gestures category: tabletop led to more communicative gestures than control condition (F(1/22) = 3.59, p = 0.071).

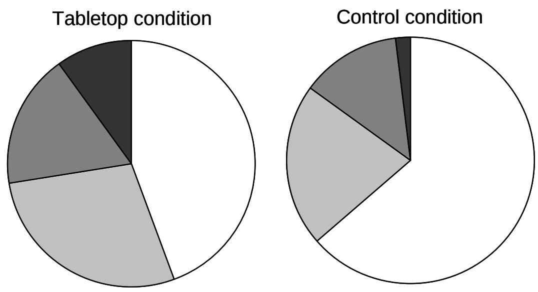

Fig. 5. Collaboration patterns in tabletop (left) and control (right) conditions: this graph represents the average contribution of the 4 participants ranked on a leader / follower scale. This figure illustrates that the contributions of the participants were significantly better balanced in the tabletop condition (p = 0.013).

The analysis of collaboration patterns showed that participants' verbal contributions (sum of all behaviors without communicative gestures) were significantly better balanced in tabletop than in control condition (F(1/22) = 7.35, p = 0.013) – i.e. they were significantly closer to the theoretical perfectly-balanced pattern. Fig. 5 presents the average collaboration patterns in both conditions: to obtain this figure, we ranked the participants of each group from the one who contributed the most (the leader) to the one who contributed the least (the follower) and averaged the data for the 6 groups. The same result applies for communicative gestures: the gestural contributions were significantly better balanced in tabletop than in control condition ($F(1/22) = 8.94$, $p = 0.007$).

6 Conclusion and future work

The tabletop condition significantly improved both subjective and collaborative dimensions of mind-mapping. First of all, the participants found that the tabletop system was more pleasant to use, improved group communication and collaboration efficiency. These effects on users' impressions could be explained e.g. by the spatial position of participants favoring social interaction, the attraction of a new technology, and/or the more active involvement of participants in this condition.

Moreover, the behavioral analysis showed that the tabletop system enabled a better collaboration: while the control condition showed strong leaders and followers, in the tabletop condition the participants collaborated in a better-balanced way. Some benefits of a tabletop system compared to a wall display or a desktop computer were previously observed by Rogers and Lindley [10] but their setting was noticeably different from ours: their tabletop device supported only single-touch interaction (with a pen) and a single viewpoint (so that the participants had to sit side by side and not around the table). They observed more interaction and role changing (swapping the possession of the input device) in the tabletop condition: it proved easier and more natural to change roles because of the use of a direct input device (a pen has to be placed directly on the display whereas a mouse controls the pointer from a distance) and because of the physical proximity of the participants to this input device (higher in the tabletop than in the wall display condition). In our experiment the collaborative benefits cannot be explained by any of these reasons because all 4 participants had the same role and interaction capacity. We could tentatively explain our results by the spatial position of people around the table, which can facilitate idea exchange, or by the attraction of a new technology, which could prompt the participants to interact with the tabletop interface and thus to give new ideas. The second hypothesis is less likely because it may have resulted in higher performance in idea generation. Therefore we hypothesize that the collaborative benefits we observed come from the around-the-table placement of people. This assumption will be tested with a new control condition where the participants will have to build a paper-and-pencil mind-map around a table. This new experiment will also complete the data about the subjective preferences expressed in the present study.

Finally, despite all the advantages of our tabletop application (subjective engagement, better collaboration, active involvement of users, focus on first-level ideas, flexibility of the mind-map display…), the experimental results showed no significant difference in the quality of outcomes between tabletop and control conditions. In the next steps of the project, we intend to focus more deeply on the performance dimension and search a way to improve it. We should develop a more accurate analysis of mind-map process and outcome to better understand the idea production mechanism. We also plan to test the influence of innovative interaction styles (see e.g. the paper metaphor [1]) on idea production and organization.

The global experimental process followed in this study (comparison of tabletop and traditional paper-and-pencil condition, variables collected…) is currently being applied to other creativity tools such as brainstorming on sticky notes in order to investigate whether the present results apply to other situations of group creativity.

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