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A Tabletop Application Environment for Generic Creativity Techniques

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Abstract: **In this article, a multi-touch based tabletop environment for supporting a generic model for creativity techniques will be introduced. Based on related work, we derive requirements for such a system or class of systems. In this regard, we will also introduce a generic model for creativity technique based problem-solving processes and discuss (group) collaboration and interaction on such multi-touch tabletop displays. These requirements are then transferred into a concept and a prototypical implementation. After this application has been discussed in detail, an evaluation of the system will be presented. Finally, conclusions and prospects for future research will be presented.**

Keywords: Creativity, Creativity Support System, Tabletop, Creativity Techniques, Multi-User Collaboration, CSCW

I. Introduction

One preferred way to guide creative problem solving processes are creativity techniques. Depending on the domain, the context, the problem type or the people involved in the (creative problem solving) process, specific creativity techniques can be suited for finding appropriate solutions. Creativity techniques are typically based on a set of certain rules, activities and constraints aiming at providing a more structured process for creative problem solving as a form of guidance [36]. The rules include so called heuristic principles such as forming associations, abstractions, analogies, combinations, variations etc. Furthermore, creativity techniques can be applied by individuals alone as well as by groups. The oldest and probably best-known (group) creativity technique is Brainstorming [30], which is nowadays applied in 92% of the companies in the United States according to a study by Fernald and Nickolenko [10].

Collaborative IT support systems for the creative process (or short Creativity Support Systems (CSS)) are able to foster creative idea generation. They reduce several negative effects occurring in non-IT supported creativity techniques (e.g. production blocking or social loafing) by providing parallel input, contribution awareness and the possibility of anonymity and distributed work [24, 3]. Those systems are typically built on a client-server architecture and are used from traditional personal computers. While this IT-support obviously emphasizes on the distributed, parallel and possibly anonymous work of each individual, one could pose the question if there are also any disadvantages.

Figure. 1: Tabletop Based Creativity Support System

In this context, Hilliges points out that "*physical, social and interaction contexts* [. . .] *play an important role in guiding cognitive processes.* [. . .] *Current computer systems already cover a variety of communication channels for distributed collaboration* [. . .] *and support for collaborative work (CSCW). However, important parts of our professional and personal life still depend on co-located collaboration and face-to-face communication, with all the nuances of facial expression and body language, and the immediacy of verbal communication*" [20, p.137]. Especially in the field of co-located collaborative creative problem solving, the core requirements of communication, coordination and interpretation [1] need to be fulfilled, but "*using single-user systems in a collaborative setting leads, in most cases, to a communication breakdown since the user's concentration has to shift away from the group and towards the computer in order to use it*" [20, p.137]. Group work using this way of IT-support also leads to stereotypical impressions of the involved users based on language, typographic, and contextual cues [37].

Due to those disadvantages of traditional IT-support for co-located situations, a paradigm shift from human-computer interaction to computer-mediated human-to-human interaction is taking place [20]. Hence, new interactive workspaces are proposed, being suited especially for creative applications [31] by providing a physical layout, which supports the interactions and collaboration between the parties involved: so called Single Display Groupware (SDG). By using such shared workspaces, people are able to collaborate directly face-to-face and in an intuitive and natural way while still maintaining most of the advantages of IT support (such as permanent recording and sustained manipulability of collaborative artifacts, etc.). Especially, SDG devices emphasize the visibility of action, which can be seen as a fundamental aspect of group awareness [6]. As others' actions and the interaction objects can be seen by all participants due to the shared workspace [15], group activity is simplified. While older studies on SDG mainly targeted co-present multi-user collaboration around a single personal computer, more novel research focuses on devices with multi-touch tabletop user-interfaces. Those interfaces intensify the regarded effects of SDG and also address an important design-principle of creativity support systems [29], as their natural and intuitive usage lowers the threshold to get started with an application and reduces the cognitive resources needed for interacting with the application [9, 21].

In this context it is our aim to investigate how collaborative creativity techniques can be facilitated in a generic way using tabletop based devices. Although already a variety of research on the support of creativity in tabletop environments exists, most of those studies have focused on artistic and less formally structured and guided creative tasks such as music performance, design, video editing, etc. In regard to a more structured support of the creative process (e.g. in the style of creativity techniques), only some studies/applications have been presented so far. Those will be regarded in the next chapter.

II. Related Work

Seth Hunter and Pattie Maes, introduced a tabletop interface for collaborative brainstorming and decision making [22]. The system includes support for two types of meetings: idea generation and deciding between a set of alternatives. In regard to decision making, the application allows for setting a dynamic background, which could for example be a matrix where ideas can be positioned in. An idea is represented just as single block of text, which can be modified, moved or deleted. Within this setting, the orientation of an idea corresponds to the user who created it and its size reflects the importance of the idea. Ideas are represented in a textual form. The input of new ideas is realized via speech recognition and, to compensate errors within the speech recognition, via a scalable multi-touch keyboard. In addition to just generating ideas, the system is connected to a database of semantically related terms which aid in finding additional associated ideas within the same context. Those associations get triggered by doing a "stroke" gesture over already existing ideas. A three month long-term evaluation, realized by lab demos, museum events and group internal usage showed that multi-touch computing seemed especially suited to augmenting collaborative discussions within social conversation spaces due to the fluid interaction with the application. Unfortunately, except of the implementation of simple brainstorming, no approach of supporting other creativity techniques was given.

In an exploratory design study, Geyer et. al [14] explored a combination of an interactive tabletop device and digital pen and paper technology for the use in full-day creativity workshops conducted with professionals from creative industries like design, film-making, art and music. They used a creativity technique similar to deBonos "Six Thinking Heads" [4] where each participant is assigned a different role. Additionally, they used themes of stimuli (e.g. collections of inspiring images) and applied their technique on different tasks. Roles as well was tasks were assigned randomly. Explicit requirements of this technique were established and transferred into a tabletop application. The application was coupled with digital pens as input mechanism. Those pens can track texts / sketches written directly on specially marked sheets of paper and are able to transmit those information via Bluetooth to the tabletop application. The user interface on the tabletop surface is similar to a zoomable pin-board where images and idea scribbles can get clustered according to the provided stimuli-themes. Additional color-coded physical tokens were used to access the available topics as well as switch between two application modes: E.g. by placing a token on a topic cluster it gets activated for browsing the related ideas. Each sheet of paper is assigned to a specific cluster by special markers on it, which is noticed by the digital pens. If no token is placed on the tabletop surface, a presentation mode gets activated. Main results from the full-day workshop were that the participants rated the tool as fun and intuitive and could see benefits for creativity workshops and the use in creative IT environments. The possibility of parallel input, the zoomable pin board and the increased group awareness were rated as most positive aspects. However, they experienced that the zoom only makes sense when one member took the role of a presenter and the rest of the collaborators taking the role of an audience. They also stated that the novelty of the applied technology combination (mainly due to the digital pens) was distracting for some participants.

Hilliges et al. [20] investigated the design guidelines for and implications of using a tabletop interface in combination with a large wall display for face-to-face group brainstorming. This application was primarily motivated by the advantages of tabletop displays for creative co-located work as already stated in the introduction. Ideas within the application are represented in the style of post-its, which are commonly used in traditional brainstorming sessions. Text-input is realized via digital pens by writing directly on the tabletop surface. However, this input method lacks optical character recognition. The wall-display mainly acts as a supplementary information space for grouping of ideas. The proposed design guidelines, which mainly aim at creating a socio-technical environment which positively affects collaborative creative problem solving, will now briefly be discussed. We will refer to those general guide-

Figure. 2: Tabletop environment for Brainstorming (source: [20])

lines for tabletop-environments targeting creativity support when describing the design of our application as well as the evaluation results presented later in this article.

DG1) Immediacy of Communication and Interaction: This design guideline mainly encompasses the avoidance of production blocking, a persistent storage of collected data, the all time accessibility of ideas to each group member and the reduction of costs for interaction and communication.

DG2) Minimize Cognitive Load: As human resources for keeping information in memory are limited, the application needs to create a context to minimize such cognitive resources, e.g. by providing an intuitive interface which minimizes additive cognitive load.

DG3) Mediate Mutual Association Activation: Generally, external stimuli are intended to induce novel associations. It is thus assumed that by creating a socio-technical environment which positively affects collaborative creativity, a context to explore the different ideas within the participants‘ knowledge network gets created.

DG4) Supporting Group Awareness and Overview: The visibility of action can be seen as the main design principle for embodied interaction [6]. Furthermore, general group awareness contributes to providing a basis for informal communication. If group members are able to understand the actions of other members in a better and more intuitive way, isolation is avoided and coordination and interpretation of others' actions are fostered.

Although the studies presented within this chapter show important cues about the practicability and usefulness of tabletop environments for creativity technique based collaborative problem solving processes, all regarded systems only focus on one specific and simple creativity technique (e.g. Brainstorming). However, many more creativity techniques exist, each incorporating its own functional patterns (see [36]). Consequently, an evaluation of creativity support in collaborative tabletop environments is always to a certain degree dependent on the creativity technique used. Also the situation in and the task for which the IT support is used may require different creativity techniques. This underlines our research goal to investigate how such a tabletop-based system providing a **generic** support for collaborative creativity techniques can be realized.

Therefore in the next chapter, a generic model for creativity techniques will be introduced. In a next step, we will regard the main characteristics of collaboration on tabletop workspaces in more detail in order to derive requirements for designing the user interface in an appropriate way. Next, we will describe our concrete implementation by referring to the design guidelines by Hilliges (see above), our generic model for creativity techniques, as well as the collaboration characteristics we want to meet. Finally, we will present an evaluation in form of an experiment conducted with 31 student participants. In this regard, quantitative as well as qualitative results of this experiment will be presented. The article will conclude with a final discussion and perspectives for promising future work.

III. A Generic Model for Creativity Technique based Problem-Solving Processes

In view of providing efficient IT support, it is necessary to have a comprehensive understanding of the domain and processes to be supported. Since our aim was to work towards a design for a tabletop interface that is capable of supporting various creativity techniques, we needed to have a precise model for these types of (creative problem solving) processes.

In previous studies of our research group, we developed such a model, incorporating the key concepts of the descriptive and cognitive process models of creativity found in psychological literature as well as the key concepts of more than 50 different creativity techniques. The model is described more detailed in [11, 12]. Since the model has important implications with respect to the design of the intended tabletop application, we briefly summarize its five most significant aspects:

CP1) General description: The main prerequisite for a creativity technique-based problem solving process to take place is a problem that needs to be solved. During the process, one or more process participants try to find ideas for solving the problem. When enough satisfying ideas are found, the process ends.

CP2) Divergent and convergent phases: Any creativity technique-based problem solving process can be regarded as a sequence of two different types of process phases: In divergent phases, ideas for a given problem are sought, while in convergent phases, the ideas from divergent phases are evaluated. Keeping these two activities strictly separated is the main principle of the brainstorming technique and many other creativity techniques.

CP3) Additional information in each of the phases: In both types of phases, additional information can be provided in order to influence the potential outcome of the process phases. E.g. by providing a random word as mental stimulus within a divergent phase, the random stimulus creativity technique tries to make the participants invent more radical ideas. In convergent phases, additional information can be displayed to make the participants focus on a specific criterion (e.g. the feasibility of an idea).

CP4) Constraints for participant actions in each of the phases: The principle behind many of the investigated creativity techniques lies in constraining the actions a user may take in a phase of the creative process in order to stimulate and focus creative forces. Some techniques impose time limits, some techniques constrain the way users are able to express their ideas in divergent phases (e.g. only sketches are allowed) and others are limiting the way users may evaluate ideas in convergent phases (e.g. allowing free comments or not).

CP5) Idea model: The process model implies a flexible idea model that has to support various ways of representing an idea (text, images and sketches). In order be more expressive, it is advisable that the different representation forms can also be mixed, e.g. it should be possible to express an idea using a textual description and to add an explanatory sketch. Since new ideas often are just new combinations of old ideas, the idea model should support combining of ideas and parts of ideas.

In a next step, before describing the concrete implementation of the guidelines and principles presented above, we will regard the characteristics of collaboration on tabletop devices in general as those also need to be taken into account for the application design.

IV. Tabletop Collaboration

As already discussed in the introduction, multi-touch tabletop devices feature several characteristics that support collaboration. From a more general point of view, they provide the means for parallel input, such that in principle several users can control an application concurrently using the same input method. The one-to-one mapping of digital and physical objects, spaces and interaction fosters immediate joint use of interaction. By that, this so called **direct manipulation** alleviates the need for social protocols to coordinate the actions within the group [26]. Moreover, the use of tangible interfaces can be used to exploit the human kinesthetic intuitive capabilities gained from life-long interaction with the physical environment. Such an **embodiment** of interaction has been largely neglected in interaction design with the prevailing conception that the mind is the sole entity that springs human action, thus "*shift*[ing] *the complexity from the from the motor actions to the decision process of what to do*" [5, p.659]. While this property can lead to the reduction of cognitive overhead with the effect of further alleviating barriers in the computer mediated interaction between collaborators, it can also facilitate the communication and the expression of the body of thought. For instance, certain physically complex tasks such as bicycling or to tie one's shoes are better explored using physical action than by verbal explanation. In this way, the physical action in such user interfaces in order to (creatively) explore possibilities or solve problems may be especially suitable for humans [23].

With respect to the different forms or schemas of collaboration mediated by the computer on the tabletop interfaces, various forms of **coupling** can be identified [35]. Coupling is a dynamic process within collaboration on such interfaces resulting in a steady flux of the group configuration. Supporting such situative group transitions is the key to permitting the dynamics of collaboration to happen, since they reflect a natural style of communication and interaction between collaborators. In a similar way, the spatial usage of the tabletop environment for personal and group tasks is comparable to the human division of space in the physical reality, helping to coordinate actions with artifacts on the interactive table or collaborators [32, 33]. Such territories can be either personal, group related or shared among all collaborators. Coupling and territoriality complement each other: coupling demands that the application can be interacted with concurrently in a flexible way by several persons from arbitrary positions around the table, thereby realizing dynamic group structure transitions. Territoriality requires that the interaction in one territory does not disrupt or interfere with interaction in others.

Morris et al. explored the impact of shared, centralized controls versus individual controls with the tabletop application "Teamtag" [27]. Regarding the group performance and the users' personal preference, it was found out that the latter was clearly the preferred method of control. This insight is supported by the research of Scott et al. [33], emphasizing the importance for parallel input and control of the application to support group awareness and group articulation. Centralized controls enforce active group awareness which is desired in certain group tasks [21] at the expense of not allowing for simultaneous action and creating disruptions in the workflow of the collaborators: "*Having to alternate and sequentialize actions caused multiple breakdowns, even though participants were highly aware of each other. Alternating actions was felt to be demanding.*" [21]. Parallel interaction also implies a more democratic group interaction: non-verbal contribution is possible for all group members as the right to control artifacts is distributed. In this way, individual users are not prioritized and thresholds for collaborating are lowered as particularly self-assured individuals can not gain full control over the application or group task in favor of "shy" ones [9]. Thus, this public interaction triggers only desired communication and negotiation. As a side note, there are also socio-psychological factors that revolve around the physical interaction such as accidentally touching the hands of other users while performing an action, which is generally regarded as unpleasant and frequently occurring with centralized controls [27].

It can be concluded that the controls in an application that unite the advantages of coupling and territoriality must be able to dynamically adapt to group configurations and therefore need to support the change between centralized and shared settings. Our application will account for these implications by allowing for a flexible conceptual division of the workspace [32] (in view of territoriality) and for sharing artifacts at the same time (in view of coupling). This is achieved via unconstrained degrees of freedom of rotating and positioning the encapsulated artifacts over the whole tabletop surface. The concrete implemented application will be presented in the following chapter.

V. Application

As a first prerequisite and element of our application, an available 42” (using a 1024x768 pixel resolution) multi-touch capable tabletop display was used [8]. This came along with a corresponding framework [7] to synchronously identify multiple gestures performed on it and thus allowed for the simultaneous collaboration within a group of users. It already turned out in early phases of the development that 4 - 6 collaborating users was the limit with respect to the used hardware (due to screen-size, etc.). Furthermore, the used tabletop device did not provide any hardware-based user-tracking mechanism.

In order to apply the generic process model to the tabletop application, we had to design the main interaction elements in accordance to the requirements introduced above. Therefore we applied a widget-based approach especially suited for multi-touch input and breaking with traditional WIMP[1] design principles. The widgets, as well as the addressed design goals will be described next. Also refer to figure 3 for a graphical overview about the implemented widgets. Each widget will be referenced to this figure by the number associated to it in round brackets.

In order to communicate the description of the problem to be solved (CP1) and to communicate additional information for each phase (CP3, CP4), a corresponding widget needed to be provided on the interface. Therefore we included an **information widget (1)** which displays the main task and further information about the current process-phase such as time limits, provided stimuli, etc. It also includes supplementary information like a “HowTo” and logged in users.

According to CP2, two types of process phases need to be supported. For divergent phases, the most important elements are the ideas that are created within the application. Based on CP5, the model for those ideas should be flexible. This led to the modeling of an idea as a set of so called “aspects” which could be texts, images or drawings. Users should be able to alter those aspects, move them to other ideas or to delete them. Therefore, we decided to represent ideas as **idea-cards (2)** in the form of real “post-its”, a concept that has already been proposed in [20] and which is in line with the design principle “form ever follows function” [34]. Aspects are separated by a small horizontal line, which can be dragged to increase the size of an aspect. In terms of functionality, the following features are available: Editing, reordering, moving (see the aspect “Hybrid” in figure 3), deleting and resizing aspects as well as changing the idea title and deleting an idea as a whole.

For convergent phases, a way to evaluate the ideas has to be considered. The **evaluation-widget (3)** consists of two different views: The first one lists all (previously) generated ideas in order to select one of them for evaluation by tapping on its title. The other (which gets triggered by selecting an idea) displays a detailed view on the idea’s aspects. There, the user is able to evaluate the idea with respect to the phase specific criterion by ratings and / or a comment box. Ideas can be cycled through by pressing the “arrow” buttons.

A **personal control widget (4)** was introduced for each user in order to allow for concurrently triggering all possible actions by each user. As a welcome side effect, we were thus able to account for each group member’s contributions and for tracking every action in the system in view of a thorough investigation. To allocate which user is executing which action, a drag and drop mechanism was implemented: a user has to press a button and slide his finger to an empty spot on the table (create) or an existing idea/aspect (edit, delete). As soon the finger gets released, the action is performed on its last position. If an area is edited, it gets locked for the time of modification so that no other user is able to change its content during this period. The use of graphical buttons for triggering actions instead of, e.g., gestures has the advantage of providing visual clues for the user (DG2). Using the control widget as starting point for each action also allowed us to activate or deactivate actions according to specific creativity techniques (CP4).

We provided the application with two different ways of textual input: **virtual on-screen keyboards (5)** as well as **coupled iPhones (6)**. One reason for using a machine friendly way of textual representations (in contrast to e.g. sketched words) was the need to be able to make modifications, which is an explicit requirement of some creativity-techniques (e.g. Brainstorming). Additionally, it allowed for an easier interoperability with other possible clients being attached to the same application core (e.g. a web-interface). Also additional services like for example searching for already generated ideas or an automated semantic evaluation get possible. By providing a keyboard (onscreen as well as iPhone) for each user, we addressed DG1 (avoidance of production-blocking, all time accessibility). Providing the wireless coupled iPhones for text-input aimed at allowing for a higher degree of freedom around the table (DG1, DG3, and DG4). Although the on-screen keyboards can be moved freely around on the tabletop surface, their initial prepositioning as well as their size (one keyboard nearly occupied a whole side of the table) would have bound the users to specific physical positions and limited the space on the screen at least in settings with more than two participants. Also the mobile device could be extended easily for providing additional functionality for sketching as well as selecting images.

As described above, the behavior and form of “real physical objects” has been adopted for the interaction and design

[1] Windows, Icons, Menus, Pointer

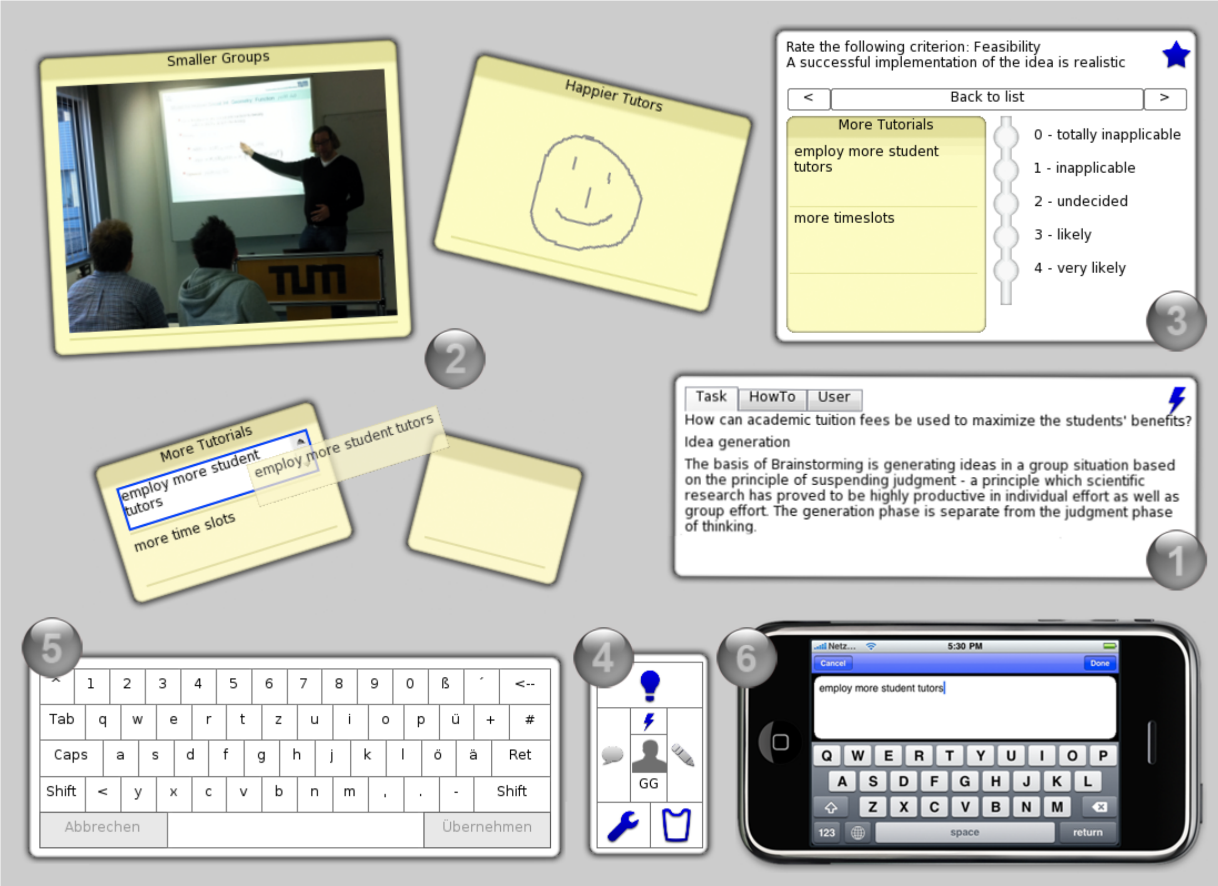

Figure. 3: Widgets of the Application and Coupled iPhone Device

of the widgets in order to reduce cognitive load (DG2). Additionally, the interaction with the widgets is mainly based on multi-touch gestures like moving, rotating and scaling. Especially, the rotate-gesture enables the users to view the scene from different angles so that they can position themselves around the table freely. The free positioning of objects also allowed the participants to form territories (refer to chapter IV). For an even more fluid and natural interaction, a physics engine based on simple rigid body dynamics (cp. e.g. [16, 17, 18]) is integrated. As pointed out in [38] this can lead to a more fluid and natural interaction with the application as well as other users (e.g. sliding an idea to another user) (DG1, DG2, DG4).

An demonstration video of the application is available online (cp. [13]).

VI. Evaluation

We evaluated the application in an experiment conducted with student participants. The setting included a creative process spanning over three divergent (idea generation) and two convergent (idea evaluation) phases. The detailed setting will be described in the following.

A. Setting

The evaluation involved a total of 31 computer science students, divided into 8 different, randomly assigned groups. Each group had to find ideas to the given problem "How can academic tuition fees be used to maximize the students' benefits?". On the one hand, students (and the problem topic) were chosen due to their availability on-site which became particularly important, as the tabletop prototype was not portable enough for being transported to another place. On the other hand, this way, we were able to evaluate in a setting, which particularly required for creative solutions as the public discussion about this topic has been ongoing in Germany for years leading to controversial results. Consequently, we aimed to stimulate this discussion by encouraging students to bring in creative (and more radical) suggestions. Figure 1 shows a photo taken during this evaluation.

After an introductory training-session (to get familiar with the iPhone based input and the interaction on the tabletop display), each group worked through a three phase long creative process, each following a different (divergent) creativity technique for idea generation. As techniques we selected Brainwriting, Unrelated Stimuli and Forced Combination. The techniques were chosen as they represent different functional patterns of human thinking (see [36] for a more detailed explanation): While Brainwriting encourages the group members to generate as much ideas as possible (with criticism not being allowed), the Unrelated Stimuli technique provides a set of completely off-topic stimulus terms (in our case "lawnmower", "water", and "outer space") to find associations which should lead to more novel and radical ideas. Finally, the Forced Combination technique instructs the group to merge ideas together. This way, the group members get encouraged to deal with the others' ideas, leading to a stronger collaboration and communication.

The duration of each phase was 10 minutes, so each group spent a total of 30 minutes for idea generation (and 20 minutes for idea evaluation), which is a typical period for such sessions [19, 28]. In a next step, the generated ideas were evaluated with respect to creativity and feasibility (cp. e.g. [2]) by using a five point Likert scale [25] from 0 (worst) to 4 (best). We also logged, how many ideas (and corresponding aspects) the users generated. Finally, a survey containing questions about the users' perception of the creative process, the team collaboration and the (tabletop) interface, was handed out to the participants (see table 2). The answers to the questions were rated according a Likert scale from -3 to $+3$ ("Strongly disagree" - $\ldots$ - "Strongly agree"). Additionally to gain an impression of the users' collaboration on the tabletop display, we made a screen recording of each session. The main quantitative as well as qualitative results will be discussed in the next section.

Table 2: Questions of the survey.

IT Support in general	
Q1	The computer support made me participating more actively (than without IT support).
Q2	The computer support helped us to produce more ideas (than without IT support).
Q3	The computer support made the session workflow more effective (than without IT support).
Q4	Within a session, I always knew what to do.
Interface	
Q5	By using the provided interface I experienced more liberty of action than at a single user PC.
Q6	The size of the tabletop display limited me in expressing ideas.
Q7	The realistic physical behavior of virtual objects made the interaction with others more intuitive.
Q8	The (virtual) iPhone keyboard handicapped me.
Group Perception	
Q9	I did not like that others were able to modify my ideas.
Q10	I perceived the synchronous and collaborative work positively.
Q11	The group configuration was suited optimally for idea generation.
Q12	The collaboration within my group was fun.

B. Results

1) Overall Results

The overall results in regard to the amount of ideas (aspects) created, as well as the rated creativity and feasibility scores can be seen in table 1. The data was determined by using resulting ideas after all three convergent phases had finished. Throughout the whole process, the respective numbers of ideas differed: E.g. after the Brainwriting phase, most ideas contained only one aspect, while after the Forced Combination phase most of those ideas got merged, leading the final 3.3 aspects per idea as presented in table 1.

Table 1: Quantitative data from the experiment.

Idea quantity (total)	107
Aspect quantity (total)	354
Aspects per idea	3.3
Idea quantitity (per participant)	3.5
Aspect quantitity (per participant)	11.4
Idea creativity mean (0 worst ... 4 best)	2.3
Idea feasibility mean (0 worst ... 4 best)	2.3

As can be seen, the modular concept of ideas as a set of aspects was adopted by our participants as they used multiple aspects for building one idea. One obvious disadvantage limiting the quantity of ideas / aspects in tabletop environments is the size of the tabletop screen. As presented in the next section, 36% of our participants were hampered in expressing their ideas by the screen size (and the according screen resolution). Even more participants could have been limited without stating it directly in the survey. One example can be seen in figure 4 which shows a three user session where particularly in the Brainwriting phase the screen limited further creation of new ideas.

2) Survey Results

The first set of statements was related to the IT support in general. 68% of the participants stated, that they participated more actively due to the IT support, what was rejected by only 16%. An even larger number (84%) stated that the IT system helped them to create more ideas than in a non-IT supported scenario - only 3% denied this. A next statement asked if the workflow (e.g. the automatic moderation of the process, the bookkeeping of ideas and contributions and the transitions between divergent and convergent phases) was perceived as more effective than in a non-IT scenario. 68% supported this statement. Last but not least, we wanted to know, of people always knew what to do within a session (e.g. by using the information widget) - 84% agreed. As only 32% stated experiences with creativity techniques (and only 19% with computer supported creativity techniques), those results show a very positive impact of our application on the participation / and process awareness of the participants.

In a next block, we asked more specifically about the tabletop interface (and the handling of the coupled iPhones). 74% experienced more liberty of action while standing, interacting and collaborating around/on the tabletop screen then when sitting at a traditional single user PC. This supports and confirms our design goals mainly in regard to DG1, DG2 and DG4. The size of the tabletop screen was judged as too small by 36%, limiting them in expressing (and generating) ideas. However, for 64% the size was large enough. As the size (and resolution) is just a technical constraint of our application, this aspect can be regarded less problematic and not as a general problem of the application itself. Nevertheless, in future work larger screens and higher resolutions should be used. Also the screen size may only be problematic/limiting for special creativity techniques aiming at a high quantity of ideas as it is the case in the Brainwriting technique. Another aspect of our application, the physics engine, was seen as a benefit by 68%, while only 26% did not see any advantage of the physics for the interaction with other users. Surprisingly, the iPhone based input posed a problem for only 13%, while 77% did not feel handicapped. As we mainly targeted computer science students, it can be

Table 3: Survey results

Question	Mean	*stdev*	Frequency (*bold font* = Mode)						
			-3	-2	-1	0	1	2	3
Q1	1.26	1.52	0	2	3	5	3	**11**	7
Q2	1.61	1.18	0	1	0	4	8	**10**	8
Q3	0.74	1.50	2	1	2	5	**12**	6	3
Q4	1.61	1.41	0	2	1	2	7	9	**10**
Q5	1.32	1.57	1	1	3	3	4	**12**	7
Q6	-0.74	1.61	3	**11**	6	0	8	3	0
Q7	0.74	1.83	2	4	2	2	**8**	**8**	5
Q8	-2.03	1.56	**20**	4	0	3	3	1	0
Q9	-2.13	1.36	**15**	13	0	0	2	0	1
Q10	2.06	1.16	0	1	1	1	1	**15**	12
Q11	1.03	1.33	1	1	1	5	**11**	9	3
Q12	2.32	0.74	0	0	0	0	5	11	**15**

assumed that those were already familiar with this novel way of text input.

The last four statements were dedicated to the users' perception of the group. A typical problem in collaborative creativity is the fact, that in some creativity techniques (such as e.g. those selected for our experiment) anyone is free to do anything with the others' ideas (e.g. delete or modify them). In the worst case this can result in production blocking (even leading to a destruction of others' ideas), which should be avoided according to DG1. Nevertheless, in our experiment only 13% did not like that other group members were able to modify their ideas, while over 90% did not experience this aspect as problematic. As aspects are the atomic data structures in the system, these structures are fine grained enough such that concurrent actions of the users do not conflict with each other. Furthermore, the increased group awareness and overview (DG4) provides a positive, effective and non-disturbing environment for group creativity. This is further stated by Q10, as again 90% stated that the synchronous and collaborative work was perceived positively. Although groups were composed randomly with most team members unfamiliar with each other, 74% rated the group configuration as optimal for generating ideas (only 10% rejected the statement). According to the last of the statements provided in the survey, all 31 participants (100%!) had fun during the session. The positive group climate induced by the co-located tabletop environment therefore obviously also addresses DG3, leading to stronger collaborative stimulation within the idea generation phase.

In addition to the quantitative data gained from to the survey as well as the evaluation of the ideas, we made several observations during the experiment and from regarding the screen recordings. As can be seen in figure 4, the participants used personal territories to cluster their generated ideas, an aspect already motivated from related literature on tabletop collaboration. For exchanging their ideas, the participants slided them into another user's territory using the implemented physics engine (territory changes - cp. table 4). Rotations, as can also be seen in table 4, were mainly used to exchange an idea with users standing "around the edge" (Rot. 90°). Typically an idea was first oriented towards a user's side before editing it. Only in a very few cases, particularly due to the iPhone based text input, we observed that some ideas were edited upside-down.

Table 4: Territory changes and rotations

	Territory Changes	Rot. 90°	Rot. 180°
Brainwriting	26,17%	35,52%	29,17%
Unrelated Stimuli	30,63%	24,40%	14,58%
Forced Combination	43,20%	40,08%	56,25%
Total	493	507	93

By regarding the videos we also experienced, that the character of specific creativity-techniques can influence how people interact with each other. While in the Brainwriting phase, most participants worked on the ideas for their own, in the Forced Combination phase they had to deal with the ideas of others and therefore started exchanging ideas more actively, breaking with a strict separation of individual workspaces. This coincides with observations made during the experiment, in which increased communication, coordination and discussion activity was taking place during the Forced Combination phase.

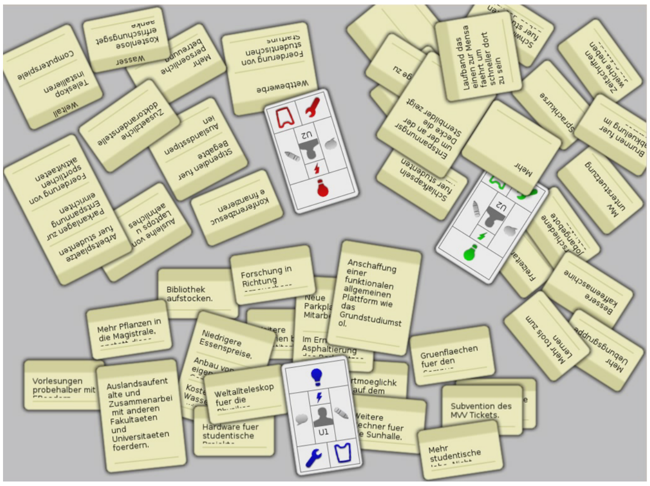

Figure. 4: Screenshot (taken from session 5 - Brainwriting phase)

In conclusion it can be said, that creativity techniques seem to differ from each other and cannot be "summarized" by regarding just one, as done in the related work with Brainstorming, which is only one out of many creativity-techniques. Within the scope of this paper it was shown, that a generic model of those techniques can be implemented on a collaborative tabletop interface and used in a productive environment. With the described prototype, a system which allows for a detailed examination of the collaborative aspects of different creativity techniques is available. Future research has to show, how the different functional patterns of creativity techniques influence the collaboration of a group.

If the observations made will still prove true with a statistical more representative mass of participants, will be shown in the scope of a detailed experiment, which will be target of our future work. Thereby especially the way of interaction (e.g. positions in the room/around the table, the posture of their shoulders and the intensity of verbal and gestural communication within each phase) shall be tracked and evaluated.

By using the described 3-phase technique, conclusions about choosing appropriate collaborative creativity-techniques for tabletop environments shall be drawn.

VII. Conclusions

In this article, we presented how a tabletop-based system providing a generic support for collaborative creativity techniques can be realized. After a review of related work, we discussed requirements for such a system based on design goals and properties of a general architecture for collaborative creativity support systems. The resulting application was introduced and an evaluation of the system via a user study was discussed in detail.

With respect to the problem of mediating effects, goals and conflicts in relation to coupling and territoriality as discussed above, our observations show that our concepts are able to achieve the desired integration and mediation to a large degree. The discrete entity concept (idea-cards, control widgets etc.) together with a total freedom with respect to positioning and orientating these artifacts allowed for e.g. arranging them in a personal territory as well as e.g. sharing them with others. Coupled display concepts (in our case introductorily realized by input via iPhone) may allow for private portions of the information space which could then be asynchronously shared with others on the table for further collaboration.

The evaluation furthermore shows (e.g. through the high degrees of user satisfaction) that the overall architectural principles of the system are well suited to support a large array of different creativity techniques effectively while at the same time allowing for integration of the advantages of an IT system (e.g. persistent storage) with the advantages of face-to-face interaction.

Future work will encompass the investigation of coupled displays where one important aspect is the support for private workspaces and their integration with the shared workspaces. We also plan to further investigate the automatic quantitative acquisition of general social context around the tabletop. This includes low level social context aspects such as e.g. interaction geometry (e.g. body distances and orientations) and presence of other persons in the neighborhood of the table (e.g. via Bluetooth), medium level aspects such as turn taking patterns in verbal conversations (if allowed by the specific technique) and high level aspects (e.g. the formation of social situations in the neighborhood of the table). These social contexts may be used to fine-tune the performance of the application on the table (e.g. via adapting the initial placements of control widgets in relation to aspects of the social network between users) or integrate the off-table environment (e.g. by playfully inviting users from a nearby social situation in a company environment to a brainstorming session on a current common problem of the group). We will also compare our evaluation/survey results to different settings/scenarios with e.g. a distributed web-interface based on the same generic model for creativity techniques.

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