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SHOW ME WHAT YOU'VE GOT: THE INFLUENCE OF COMBINED SKETCHING ON IDEA GENERATION IN TEAMS

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ABSTRACT
The present study investigates the influence of common sketching in teams on the idea generation process in early concept generation. Thirty-six teams of three design students were given a small task in which they were asked to come up with visualized ideas. In the control groups, team members sketched on an individual sheet of paper while working in a team. As expected, the teams sketching individually produced more in total and more diverse ideas. No difference was found between the quality and innovativeness of the ideas. Also according to the hypotheses, individually sketching teams elaborated less on their ideas and explained their own ideas more. The teams did not differ in their satisfaction with the final result. The results suggest that common sketching did serve as a common ground in the group that leads to shared views and ideas. This, however, goes along with less productivity of ideas.

Keywords: design collaboration, sketching, conceptualization

1. INTRODUCTION
Most design activities nowadays are done in teams. This asks for individual designers to communicate their views and ideas about the problem and solution to each other. These ideas, however, are unlikely to be fixed and well defined and can therefore only vaguely be described. Even for individual designers, understanding the problem can be a difficult task. This task is even more demanding if different members of a design team with distinctive or even conflicting views have to communicate about it with each other. Often, designers use external representations of their thoughts to facilitate the communication process. Depending on the domain, hand drawn sketches or CAD systems are often used for that purpose. Especially in early phases of idea generation, in which concepts are generated rather than that existing ideas are analyzed and developed, sketching can facilitate the communication between the individual designers. Although the effect of sketching as a tool in design, both individually as in groups, have been studied before, the influence of sketching as a common ground within a design team and its influence on the group process have received far less attention. This paper presents an empirical study examining the influence of the way in which designers sketch their ideas. More specifically, we address the question whether ideas are exchanged better by sketching one's ideas individually or together in a team when creating a new design in a brainstorming session.

Sketching in design teams
Design concepts, even while being created, constitute artifacts that resemble objects in the real world. Designers hold mental images of these artifacts that assist them during their thinking process [1]. These mental images have to be manipulated and altered constantly during the design process. Although the preconditions and circumstances in which sketching is required is not yet fully understood, and it has been shown that it does not necessarily lead to better results [2], designers often use sketches to facilitate thinking.
However, sketching is generally viewed as the preferred form of representation for designers and is often viewed as a necessary part of the design process [3]. Sketching is a particularly preferred aid to extent visual imagery in visual designs. The use of visual representations by sketching the design provides a memory extension which lowers the cognitive load that is needed for the visual design process [4]. Once a design idea is represented in a sketch, the designer does not need to put any

cognitive load on mentally representing the object. In turn, it takes less effort for the designer to mentally envision and manipulate the still unformulated object as its representation is visually present. Therefore, designers who sketch during the design process perceive problems as less difficult [5]. The use of visual representations has been argued to facilitate design problem solving by making the designer's mental images more explicit. Furthermore, designers who used sketches could infer more relations between components of complex concepts [5]. This supports the idea that sketches contribute to a better and deeper understanding of one's own ideas.

Research has shown that during design collaboration the use of shared sketches within the design team facilitated a spatial design task by providing a common ground that contributed to a shared focus of attention [6], thereby ensuring that all team members were on the same page. This led to a more efficient design collaboration and resulted in a better product. Furthermore, the shared sketches served as a common object for communication, encouraging the interaction between the team members. Participants therefore enjoyed the task more when they could work with a common sketch as compared to when they worked without a sketch.

It has also been argued that the use of sketches in design teams functions as a common ground for design teams when objects are designed [7]. When designing objects, sketches function as a means to communicate ideas and concepts, and to build on these ideas for finding possible solutions. While doing so, designers must negotiate about their explicit ideas before this can lead to an understanding of what is agreed-upon.

Idea generation in teams

During early phases of conceptualizing a design, divergent thinking is generally applied. In order to come up with innovative solutions, many and diverse ideas are preferred. Often, groups brainstorm to come up with a large number of ideas, especially if input from specialized experts is needed. Though brainstorming in groups is a commonly used method, it is known to bring about productivity losses [e.g., 8,9]. One important reason is that team members must take turns to express their ideas. During this process, members may get distracted by ideas of the other team members, thereby postponing and forgetting their own ideas. By this disruption, the image activation is disturbed, which leads to less diverse ideas, which in turn also leads to less productivity [10]. In the same study, it was found that ideas suggested by others facilitate the activation of problem-relevant knowledge. The stimulation of ideas by such brainstorming sessions is thus possible; however, this does not lead to more ideas. However, the stimulation should activate analysis of the ideas, thereby leading to a deeper understanding of the concepts. If only one sketch is available for stimulation at a time, all team members should think about the same content. In turn, this should serve as a common ground for the team.

Members of a design team should hold similar views about important aspects of how to solve the given design problem. These can be aspects of the task, such as the problem statement and requirements, the process, and how to approach the task and the team. Teams that hold shared mental models about these aspects are assumed to perform better [11]. Following this line of reasoning, teams that have a common ground build a shared mental model more easily, resulting in more similar views on the task, the team, and the process.

Research question and hypotheses

In this paper, we want to examine how working on a sketch together helps to create a common ground within a team. Moreover, we want to study the effect of combined sketching on the productivity and the quality of the resulting concept.

As described above, individuals are more productive and generate more ideas when brainstorming than groups. The question is, however, what happens when team members sketch and develop their ideas together while being in a team setting. Team members should more easily create a shared mental model about the task in general and the solution in particular. This should lead to a deeper understanding of the task. On the other hand, when team members share more of their mental models, there is not as much room for diverse ideas. We therefore hypothesize that teams that produce and sketch their ideas individually will produce more ideas (*hypothesis 1a*) and more diverse ideas (*hypothesis 1b*) than members that sketch together.

While working on one sketch, team members focus their attention on the idea that is produced. It can thus be expected that each idea received some thought by all team members. This should lead to more

analysis of those ideas, resulting in more utterances of elaboration. We hypothesize that teams that sketch together on a team level will elaborate more (*hypothesis 2a*) compared to teams that sketch individually. Moreover, as sketches are discussed while producing, less explanations (describing aspects of the own idea) about the sketches should be necessary. We therefore hypothesize fewer explanations in teams with combined sketching (*hypothesis 2b*).
We expect that teams that sketch together should focus on every idea in more detail, providing a deeper analysis for every idea right from the beginning. In other words, every idea is developed by three designers rather than one, whereas designers that sketch individually might not explain their ideas to the others in much detail. We hypothesize that team sketching combined leads to ideas of higher quality (*hypothesis 3a*). On the other hand, well considered ideas have to be approved by all team members, asking for a consensus. This should hinder creative "out-of-the-box" thinking, resulting in less innovative ideas in the team condition (*hypothesis 3b*).
Finally, team members who work on one combined sketch and who spend more time working on only a single idea at a time should give these ideas more thought, whereas team members that sketch individually might have to agree on an idea that they have not considered before. Therefore, we hypothesize that teams who sketched together should be more satisfied with the final idea (*hypothesis 4*).

2. METHOD AND DATA COLLECTION

Participants
One-hundred-and-eight participants (26 females, 82 males; mean age = 20, SD = 1.7) from a Technical University participated in exchange for a coupon of 5€. All but three participants were Industrial Design Engineering students, on average in their second year.

Design
The study had a single factor (sketching: individual vs. combined) between-subject design. Participants were randomly assigned to 17 ad-hoc teams of three members each in which they sketched their ideas individually, and 19 teams in which they sketched together. Teams in both experimental conditions were instructed to work together as a team and to choose and present a joint concept at the end.

Measures
The dependent measures were: the number of ideas, the diversity of ideas, the amount of elaboration about ideas, the amount of explanation about ideas, the quality and creativity of the final concept, and the participants' satisfaction with the final result. To guarantee an objective evaluation of the sketches made by the participants during the task, neutral presentation papers or photocopies of the presented concept were used for the coding.
The number of ideas was based on the number of the produced sketches. Video recordings of the full design process were made to make sure that all ideas were recognized. A new idea was defined as a new concept sketch or a distinctive change of an already existing sketch.
To assess the diversity of the ideas, five categories of the concepts were defined based on the existing sketches. Each idea was then attributed to one of these categories. Diversity was defined as the number of categories that ideas could be assigned to.
To measure the degree to which teams elaborated their ideas and explained those to each other, videos of 26 groups (13 for each condition) were analyzed in depth. The actions of the team members were coded based on spoken utterances. To cover all instances, a distinction was made between the development of new ideas, the elaboration of new ideas (also including related task requirements), explanations about given ideas, and unrelated informal talk. Every time a team member mentioned a new idea, it was coded in terms of these categories and counted as an instance.
The quality of the sketches was evaluated by three different raters independently based on four independent aspects. Following Diehl and Stroebe [8], the concepts were rated on a 5-point scale for originality and feasibility (functionality). Additionally, the styling of the ideas was evaluated as one aspect to determine the quality of the sketches. Furthermore, it was assessed whether all or most requirements given in the task description (e.g., restrictions on the measures) were incorporated in the concept; if not, this led to a negative evaluation. After all four aspects were rated, all three raters

agreed on a score between 1 and 5 for each concept. The rating of the ideas' originality was also used independently in the analysis and is henceforth called innovativeness.
Finally, the satisfaction of the team members about the final concept was measured using a 7-point Likert scale. Moreover, participants were asked whether they thought they would have arrived at a better solution if they had worked on their own, without having to make a team decision. Additionally, five questions on a 7-point Likert scale about the perceived coordination and the perceived process were asked, respectively. These were added to check whether teams from the two conditions differed in their perceived way of working together.

Procedure

All participants received an instruction in which the example of a concept design of a multitool for design students was presented. For this tool, several required compartments were given in the instruction so that not much time is needed to spend thinking about requirements. After having read the two instruction pages, participants had 30 minutes to develop a visual design of how such a tool could look like. They were explicitly instructed not to think much about the usability or functionality of the tool, but to focus on the visual concept design instead. Furthermore, participants were told to come up with an innovative idea. Figure 1 shows some example sketches that illustrate three concepts of such a tool. Participants in the *combined sketches* condition were given one A2 sketching paper, which they had to share for sketching. Participants in the *individual sketching* condition could each use one A3 paper. In both conditions, extra paper was available on the table if needed. After 20 minutes, participants were reminded that they have ten minutes left to finish their concept, and that they have to agree on one joint concept. At the end of the task, participants had to present their chosen concept giving a two minute presentation.

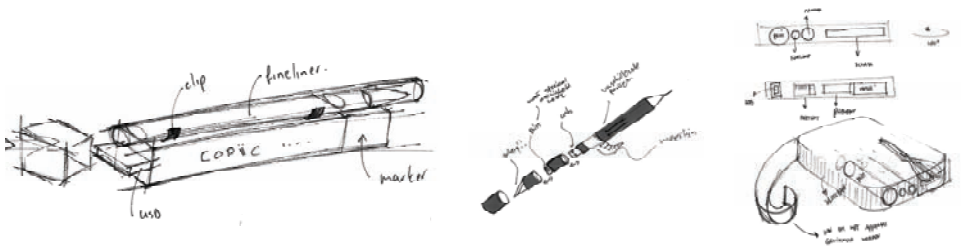

Figure 1: Example sketches

3. RESULTS

The average number of ideas for teams sketching individually and combined is shown in Figure 2a. Teams that sketched individually produced more ideas than groups that worked together on one sketch ($t(34)=2.46$, $p<.05$). *Hypothesis 1a* is thus supported.
Teams that sketched individually also produced more diverse ideas, thereby exploring more potential solutions (see Figure 1b). The ideas of those groups were also more diverse ($t(34)=2.14$, $p<.05$). This implies that team members did not only generate more ideas, but that the ideas were also different from each other. *Hypothesis 1b* is therefore also supported. The number of ideas and the diversity are strongly related to each other ($r=.69$, $p<.01$).
No significant difference was found in the evaluation of the quality of the final result ($t(34)=.03$). For the innovativeness, no difference was found either ($t(34)=.61$). *Hypotheses 2a* and *2b* are thus not supported. However, creativity was related to the diversity of ideas ($r=.33$, $p<.05$), suggesting that when more diverse ideas are created, this goes together with a more innovative final outcome.
In order to investigate what team members were discussing while working together, 26 teams were selected and qualitatively studied in detail. These groups were counterbalanced so that an even number of productive and successful teams were in both conditions. The sample size of 2x13 teams was selected to enable statistical testing. Figure 3a shows the amount of elaboration in teams. The analysis revealed that in the combined sketching condition, members elaborated more on their ideas $t(24)=1.76$, $p=.09$. Although this is only a marginally significant trend, it suggests that teams that sketch together have the tendency to elaborate more on their ideas. Given the limited sample size, we assume that a

larger number of teams would have provided us with a significant result. *Hypothesis 3a* is thus partially supported.

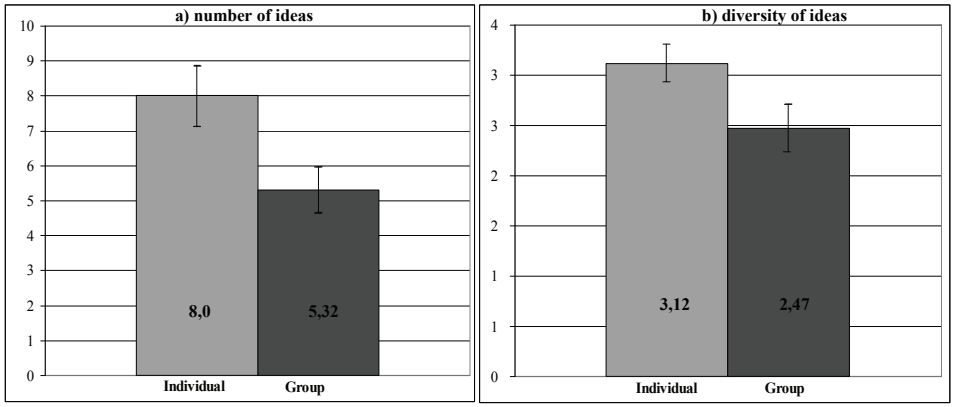

Figure 2: Number (a) and diversity (b) of ideas

In Figure 3b, the average explanations are presented. Teams in the combined sketching condition needed fewer explanations during the design process ($t(24)=2.25$, $p<.05$). This effect could mainly be explained by the fact that team members in the individual sketching condition did not continuously keep track of the ideas that the others produced. This could have resulted in more need for clarification, which would not have been necessary if there had been only one focus of attention all the time.

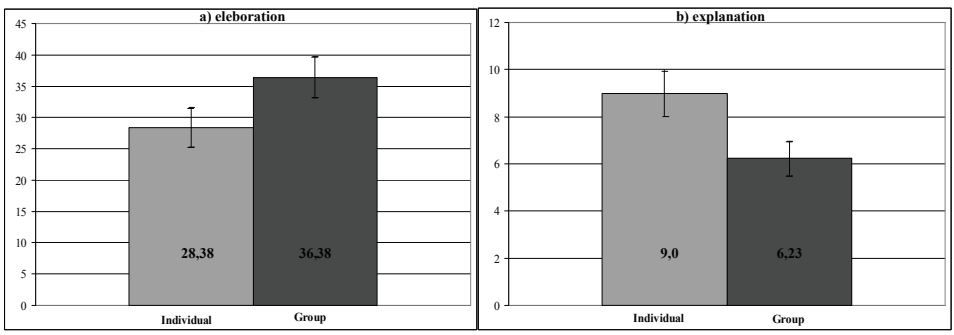

Figure 3: Elaboration (a) and explanation (b) in teams

No difference was found regarding satisfaction with the final result; hence *hypothesis 4* is not supported. However, satisfaction was related to the perceived structure of the process ($r=.34$, $p<.05$). Teams who perceived the process as structured were more satisfied with the final result. The same relationship was found between satisfaction and perceived coordination within the team ($r=.46$, $p<.01$). No difference was found for the perceived process and the perceived coordination within the teams across the two conditions.

4. DISCUSSION

The results are in line with earlier findings that generating ideas within a team come at a cost of productivity losses. If the mere number of ideas is important, this study has shown that the more aggregated individuals work, the fewer and less diverse their ideas are. Moreover, this study shows that the processes leading to productivity loss have benefits as well. Working on a common sketch serves as a common ground, forcing team members to focus on one sketch at the time. By doing so, members are encouraged to consider every idea more carefully compared to when they work on

individual sketches. If only one sketch is present, results indicate that team members tend to elaborate and reinterpret more often, suggesting that they spend more effort on each others ideas. This is in line with a previous finding, in which sketches have been found to provide a more integrated group process, though these did not support the reinterpretation of each others ideas [12].
Building on that, it is likely that team members not only develop a shared mental model about the task at hand, but also about the process and the team as they work in an integrated group process in which they need to guide their actions accordingly. Doing so, they need a good understanding of each other and what they are working on at the moment. The use of sketches in the team as a common ground can thus help to create a shared mental model. In this study, we have shown that the mere use of sketches is not enough to create sharedness - the sketches have to be used commonly within the team in order to function as a common ground. This is a new finding, because this study focuses on how sketches were used in a team rather than what effect sketching as such had. Again, the important issue is that team member work on one common sketch. The mere use of a whiteboard might not be enough, team members have to actively work together.
Interestingly, the satisfaction with the end result in the team was related to the perceived structure of the process and the perceived coordination within the team. Although we can not argue for a causal relation, we argue that even in conceptualization phases, at least for design students, following a structured approach is beneficial.
In this study, design students with some sketching experience participated. Although this was suited for the simple conceptual design task, experienced designers in real life settings might differ in their behavior. For example, practicing designers were found to be more interpretive and showed more fixation-resistant than novices [13]. Additionally, expert designers are assumed to benefit more from sketches than novices [14]. For them, the benefit of having a common sketch as a common ground might therefore be even more important. A study that investigates the differences between novice and expert designers on how they use sketches as a common ground would be an interesting follow-up study.

5. CONCLUSION

Although many studies on sketching during the design process have been done in the past, there still is little understanding when and how sketches are a necessary and a useful design tool. We showed that the common sketches in a team aid to the development of a shared mental model. The conclusion is that sketching is the preferred technique in teams when it is important that teams develop sharedness about their task. Team members learn a lot about their views on the problem, the process, and each other while discussing it. When the conceptualization phase is the beginning of a longer project, we would advice teams to work closely together to share their views and ideas. If diverse output is the goal, team members might be better off working individually.

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