A Study on the Acceptance of Computer-Supported Morphological Analysis

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Abstract

Ideation and innovation can be supported by more or less formalized creativity methods such as brainstorming or morphological analysis. While previous studies have shown increased productivity with computer-supported versions of such methods, their paper-based variants still largely prevail because of non-performance-related factors.

We conducted a study with 23 well-motivated and creative participants ideating on hypothetical business ideas using morphological analysis and found that – in contrast to other studies – software support was largely preferred over paper. This might partly be attributed to the more rigid structure of this method, but also to specific benefits of the software such as anonymity. The results of our study raise interesting questions for further investigation.

1. Introduction

Being part of increasingly competitive and cost-sensitive markets, more and more organizations realize the strategic importance of innovation to sustain themselves and achieve a competitive advantage. As a result, these organizations aim to leverage the skills, experience and creative potential of their employees using various processes, tools and techniques such as innovation management and ideation workshops across all organizational levels.

Morphological analysis (MA) is a structured approach to ideation and problem solving typically conducted in teamwork. It was pioneered by Fritz Zwicky in the 1960's and consists of five steps [10]:

1. Formulate the issue at hand as concise as possible
2. Decompose the problem into subproblems and generate partial solutions to the subproblems
3. Create the so-called Morphological Box (MB), which is a compact representation of your formal solution space
4. Start evaluating all configurations contained in the MB (check whether they serve your purpose)
5. Select optimally suitable solutions and apply them

MA is particularly suitable for problems whose solution candidates can be represented as concrete configurations sharing a common abstract form as for example in system or product design. The MB is a matrix representation of the formal solution space of the MA.

Figure 1 shows an example of MA in the product design of a table. A product idea is generated by selecting a configuration within the MB.

Material	Wood	Glass	Metal	
Function	Eating	Writing	Handcraft	
No. of legs	1	2	4	
Form of table surface	round	square	rectangle	oval

Figure 1. Example of a morphological box for a table with one combination marked as a potential solution

Advances of classical MA and software-support have been proposed and developed (e.g. Ritchey in [9]). However, advice literature remains to refer to the classical MA approach of Zwicky and typically does not reference MA software. Key reasons for this might be higher (perceived) complexity of advanced MA process models and/or little technology acceptance of currently available MA software implementations.

This paper is based on Zwicky's original formulation of MA. The key idea of MA is to (1) identify and define the major decision parameters of the problem, to then (2) assign a range of possible decisions (*values*) to each of the parameters, and finally (3) to generate potential solutions by investigating possible relationships (configurations) of the decision or design space.

Another well-known creativity technique is brainstorming which was introduced by Osborn in the 1950's [8]. In a classic brainstorming session, group members are expected to be in the same room and freely speak out their thoughts and ideas while following the four rules suggested by Osborn: (1) focus on quantity, (2) no criticism, (3) all, even wild and unusual ideas are welcome, and (4) combine and improve on ideas.

A large body of empirical research found major process losses in verbal brainstorming such as production blocking [4, 5], evaluation apprehension [1] or social loafing [7]. Variations of the brainstorming concept have been proposed to address these issues such as nominal group brainstorming and electronic brainstorming [3].

Despite evidence showing that nominal group and electronic brainstorming tend to yield more ideas than verbal brainstorming, the latter is more widely used in practice. Dennis and Reinicke suggest that the acceptance of electronic brainstorming is low because users are not only concerned with the quantity and quality of the output (performance-related criteria) but consider other factors (i.e. group well-being and member support) to be important as well [2]. Based on theoretical arguments and a survey of 131 part-time MBA students, they conclude that verbal brainstorming contributes more to group well-being and member support than nominal group or electronic brainstorming.

In this paper, we investigate the acceptance of computer support for collaborative ideation using MA. While brainstorming is a loosely structured creativity technique, MA imposes more structure on the ideation process and group interaction. We believe that the perceived usefulness of software support is higher for structured, artifact-oriented creativity techniques such as MA than for less structured techniques such as brainstorming. Thus, we expect that the former should be more readily accepted by users than the latter. While Dennis et al. [2] indicate that verbal brainstorming is preferred over electronic brainstorming, the hypothesis investigated in this paper is that users prefer software for more structured, artefact-oriented creativity techniques such as MA over a pen-and-paper variant. In order to investigate this hypothesis, we developed a MA software prototype and conducted a qualitative study to identify major factors for the acceptance of software-supported MA. We compare a software- with a paper-based creativity session in a field experiment.

2. Method

We developed a software for computer-supported MA and conducted a field experiment with 23 students. The students were asked to generate ideas for innovative products and evaluate their group's ideas in either of two settings: (1) using MA software and (2) using a paper-based MA approach. Afterwards participants were asked to fill in an online questionnaire about their experience with each setting.

Finally they were asked to perform a personality test to assess the participants' personality traits.

2.1. Participants

The 23 students that participated in the experiment are all enrolled in the same class of a sideline study program on technology and management and come from various study backgrounds, mainly business studies, computer science and electrical engineering. The class is composed of 24 students but one was missing on the day of the experiment.

All participants were enrolled in a seven week course with an expected full-time commitment to the course work and lectures. The students got to know each other in a three-day kickoff meeting shortly before the beginning of the course. The study was conducted at the end of week four. By this point, students had been working together in two different team allocations of 4-6 members during these four weeks.

Table 1. Participants' demographics

Factor	**No.**	**Percentage**
Gender		
Male	18	78.3
Female	5	21.7
Age		
20-21	3	13.0
22-23	8	34.8
24-25	7	30.4
26-27	3	13.0
28-29	2	8.7
Study Background		
Business Studies	6	26.1
Computer Science	8	34.8
Electrical Engineering	5	21.7
Mechanical Engineering	1	4.3
Communication Science	1	4.3
Consumer Affairs	2	8.7

Table 2. Participants' scores on the Big-Five personality test (scores between 10 and 50)

Factor	Mean	SD
Extraversion	35.1	5.5
Agreeableness	37.0	6.3
Conscientiousness	33.4	6.6
Emotional Stability	31.0	2.6
Intellect / Imagination	38.5	2.3

It was part of the course assignments to come up with new business and product ideas in the field of education. Hence, students were motivated to generate ideas within the experiment since these ideas would also contribute to their curricular project work.

The students were already assigned into four teams as part of the second phase of the course they attended. Three teams consisted of 6 members (teams 1, 2 and 4), one team consisted of 5 (team 3). Each team was made up of students with a business studies background, students with a technical studies background as well as students with a background other than business and technology.

2.2. The Software System

We designed a web-based, real-time group ideation system which supports collaborative MA in small groups (preferably less than 6-7 per group). It allows virtual collaboration for distributed teams as well as collaboration on the spot.

2.3. Experimental Setup

The experiment was conducted in two rooms of similar size, one reserved for the paper-based ideation session, one for the software-based ideation session.

One of the authors gave an introduction at the beginning of the experiment. First, the concept of the MB as a creativity method was introduced and followed by an explanation of the procedure for evaluating the generated ideas. Then, the first task and schedule of the experiment were presented to the participants, the second task was introduced at the beginning of the second session.

The goal of both tasks was to come up with product ideas in the field of education.

The first task description was: "*Imagine you are part of a company producing blackboards, serving 10% of the annual German market. The goal of your ideation session is: To come up with new, 'fancy' product ideas starting from your current product.*"

The second task was: "*Imagine you are part of a company producing school benches, serving 10% of the annual German market. The goal of your ideation session is: To come up with new, 'fancy' product ideas starting from your current product.*"

The schedule was given as follows. The same time constraints were imposed on each part of each session:

1. **Create the morphological box** (20 min)
   Participants collaboratively defined the parameters of the problem and listed potential values.
2. **Generating ideas** (20 min)
   Participants selected configurations of values from the shared morphological box and added one idea per configuration.
3. **Rating ideas** (20 min)
   Participants rated ideas on a scale from 1 to 7 with respect to two factors: originality and feasibility (which is related to the problem statement). These two factors were the axes of the results matrix.

The students were asked not to talk about the experiment until the end of the two sessions.

Following the introduction to the experiment, two teams (teams 1 and 2) stayed in the room to conduct the software-based ideation session while the two remaining teams (teams 3 and 4) were guided to the other room where they conducted the paper-based session on the same task. Afterwards, teams switched rooms and approaches, respectively, for the second task, which was disclosed right at the beginning of that second session.

In the software-based ideation session, the students were asked to log in with their user id, which allowed them to stay anonymous within the group they were currently working in. Students were not allowed to talk in the software-based setting. As a result, participants were anonymous in contrast to the paper-based setting during which participants were allowed to discuss throughout the session.

In the software session, participants constructed the morphological box by real-time collaboration. In the idea generation phase, they individually selected a configuration from the morphological box, entered a name for each idea and provided a textual description. In the rating phase, they were shown all ideas of their team's members except their own. By clicking on a specific idea item, they were able to read its description. They rated the idea by assigning two scores for originality and feasibility. Their rating was displayed in a results matrix.

In the paper-based version, participants jointly created the morphological box on a poster. In the idea generation phase, they drew lines on the poster which represented the combination of values they chose for an idea. Then, they wrote down their idea on a sticky note. In the rating phase, they were provided with the results matrix printed on a poster (axes originality and feasibility, ratings from 1 to 7; equivalent to the software variant). On that matrix, they placed the sticky notes of the ideas according to their rating.

The experiment concluded with a questionnaire segment during which participants were not allowed to talk to each other. The questionnaire contained questions on the users' perception and satisfaction with using the software or participating in the paper-based ideation sessions and on their satisfaction with the results from both sessions. The online questionnaire contained questions with ratings on a Likert-scale from 1-7 and text fields for remarks and explanations. Questions on the arguments for their preference on the first page and a number of subsequent questions were intentionally posed as open questions in order to gather input for hypotheses that could then be tested by posing more specific questions in subsequent larger, quantitative studies.

One week after the field experiment, students were asked to anonymously take part in a personality assessment test [6]. Personality assessment results were mapped to the associated experiment survey data by pseudonymous user IDs without disclosing personal information.

We evaluated the performance based on the number of generated ideas and the ratings of the ideas given by the team members within the session. Finally, we looked at the remarks of the students on why they preferred one or the other method or why they might have been indifferent. The remarks were coded independently by two authors on overarching motives. Differences in ratings were discussed to find a common agreement.

3. Results

A major result of the study is that software-based MA was preferred over the paper-based version. 13 out of the 23 participants preferred the software version, whereas only 4 participants preferred the paper-based version. The remaining participants were neutral.

Table 3. Participants' preferences for software vs. paper-based MA

Preference	Number of participants	Percentage
Software	13	56.5
Pen & Paper	4	17.4
No preference	6	26.1
Total	**23**	**100**

Analyzing the arguments, we found that most arguments in favor of the software version referred to factors influencing the task performance on the ideation session. In fact, all participants who preferred the software solution or were neutral, provided one or more arguments regarding task performance. While arguments listed by those in favor of the software mainly focused on performance-related benefits, participants that preferred the paper-based version did not state any performance-related arguments as reasons for their preference. Neutral participants focused both on performance–related and non-performance related factors, mentioning benefits for both the software-based and the paper-based version.

Five out of six neutral participants and all four supporters of the paper-based variant provided non-performance-related arguments, but only with regards to the paper-based version.

In the following, we will summarize the main lines of argument provided by participants. First, we will focus on performance-related arguments. Then, we will discuss non-performance-related arguments. While arguments on task performance were only mentioned to support the software version, non-performance-related arguments were brought up for and against both variants.

The primary line of argument in favor of the software version was mainly based on task-performance-related aspects. The participants were mainly referring to higher efficiency, better process support and better quality of the output.

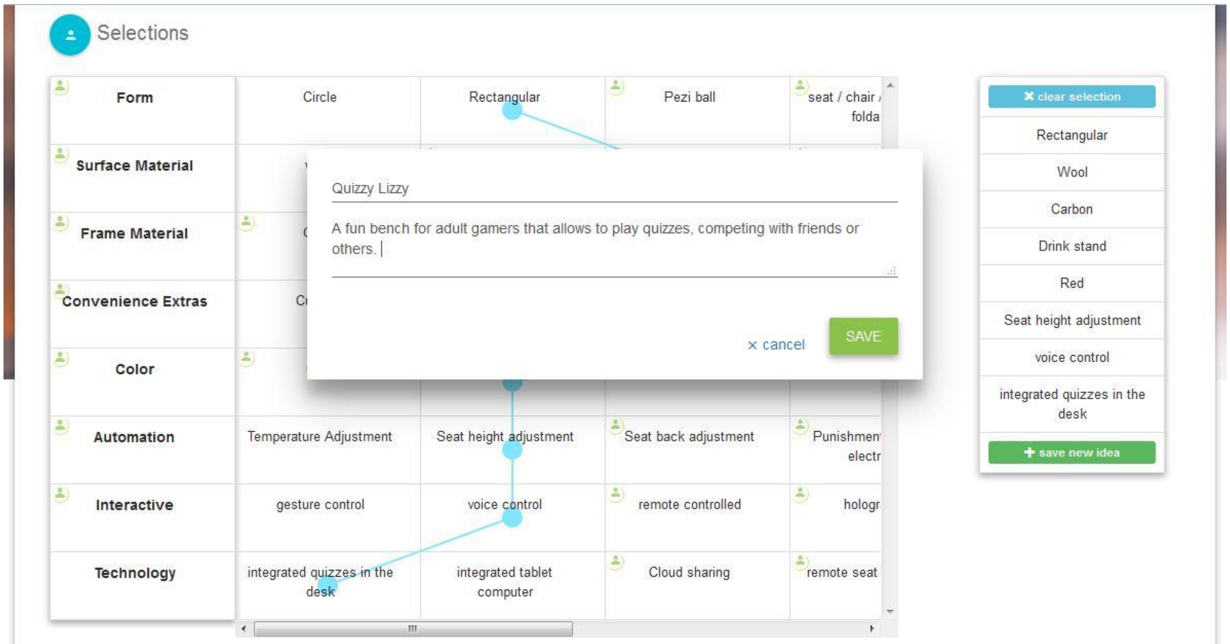

Figure 2. Generating ideas in software based on collaboratively constructed morphological box

The higher efficiency of the software was attributed mainly to the parallelization of the process across all phases (morphological box creation, idea generation and idea evaluation) and the missing discussion ("*no discussion, which allowed for clear decisions regarding the validity of each idea [...] This was more efficient*", "*everybody could work at the same time*", "*It was easier to simultaneously collect attributes and ideas*", "*easier to parallelize*", "*no time lost for arguing*", "*more efficient, whereas if you communicate together, you really use up all the time*" or more general comments "*A lot faster*", "*people can write without any problem*").

Process support was perceived to be higher in the software setting and primarily justified with the visual representation features of the software throughout all process steps (arguments mentioned among others were "*better overview*", "*more structured*", "*less chaotic*", "*less clutter*", "*cleaner*", "*no limitation in row and column entries*", "*rating the ideas in 4 quadrants was done much better in the software*"). In contrast, the paper-based version was considered rather chaotic ("*The paper-based version got very messy and chaotic*", "*the other 'paths' were more distracting*", "*too many lines on paper in paper-based version*", "*when trying to define the lines, it was just a huge mess of lines, attributes and properties.*").

Two participants claimed that the use of the software led to more creative output, which they explained with the software encouraging participants to enter wilder, unusual ideas ("*potentially crazier ideas*", "*Although some idea seemed unreasonable at first (which in a paper-based version would've been scratched out), on the platform they led to pretty radical ideas which was voted on by most people.*").

Non-performance-related criteria were also highly relevant to participants, some supporting the software, some the paper-based variant.

Although participants who were in favor of the software version mainly mentioned performance-related criteria (all 13 mentioned some), some of them (4 participants out of the 13 that preferred the software version) also stated non-performance-related criteria that made them favor the software version, which we will list below.

The non-performance related factors in favor of the software version centered on better group dynamics and on addressing preferences and needs of certain personalities better. ("*people did not try to assert their own ideas with bias*", in contrast to "*judgement within the team and no 100% free idea flow*" [in paper-based version], "*We could ideate without being interrupted by others*", "*easier for shy people to add their ideas*", "*You feel more satisfied while including any ideas even if it was not that unique*", "*easier to develop own ideas […], because you were not interrupted or distracted by other people*"). In addition, several participants stated that the software was easier or more comfortable to use.

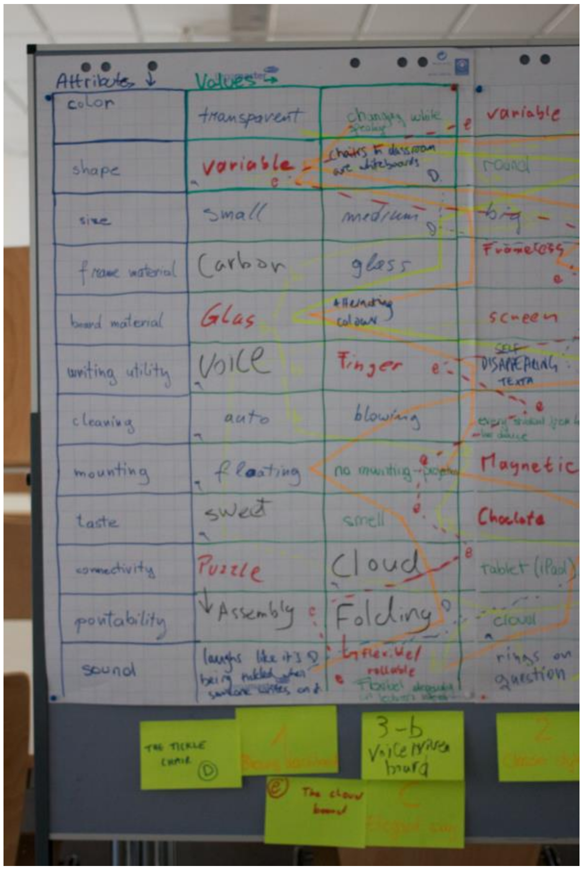

Figure 3. Morphological box, combinations and some resulting ideas in a paper-based session

In contrast, people who preferred the paper-based version only mentioned non-performance-related arguments. These non-performance-related arguments (some of them were also mentioned by neutral participants) primarily referred to better communication among team members, which allows participants to clarify and build upon other ideas ("*better building on teammates ideas*", "*better to transport the concept of an idea before rating*", "*to ask what the fellow students mean by certain terms*", "*pitching the final ideas on the flip chart seemed more beneficial in terms of discussing them in person*"). "*Communication*" or "*discussion*" were also mentioned by several participants in a more general sense without elaborating on concrete benefits. Other participants referred to a positive impact of the interaction on group well-being ("*More of a brainstorming for the whole team as a one group*", "*the Team Interaction was nice*").

One participant mentioned their individual needs were met better ("*you also could bend the system more easily to your personal workflow*"), another stated that "*due to less 'anonymity'* [Authors' note: the paper-based version] *had less 'bullshitting'*".

Table 4. Number of ideas

	Software	Paper
Number of ideas		
Team 1	19	15
Team 2	24	13
Team 3	17	7
Team 4	26	26
Total	86	61
Mean at team-level	21.5	15.25
SD team-level	3.64	6.87
Mean at individual level	3.73	2.60
SD at individual level	0.46	1.08

As we can see in table 4, the number of ideas generated was higher in the software session (86 vs. 61 in the paper-based session). However, the feasibility and the originality of ideas was lower (table 5). This is in alignment with the participant's subjective self-assessment (see table 6). In terms of overall idea quality, participants should have preferred the paper-based version, also in terms of feasibility and originality (except for the negligible .04 higher rating of the quality of their team ideas in the software). However, they preferred the software variant with respect to task performance and some non-performance-related aspects. The latter are commonly perceived as benefits of verbal brainstorming.

Out of the four people who preferred the paper based version, three were in team 4. This is the only team that did not produce more ideas in the software session (26 ideas in both sessions).

Table 5. Ratings of ideas within the sessions on a 7-point Likert scale (1 = low, 7 = high)

	Software	Paper
Originality rating of ideas		
Team 1	4.18	5.07
Team 2	4.29	4.75
Team 3	4.24	4.39
Team 4	3.73	4.09
Mean	4.11	4.57
Standard deviation	0.22	0.37
Feasibility rating of ideas		
Team 1	3.73	4.02
Team 2	3.92	4.40
Team 3	3.97	4.07
Team 4	3.81	4.09
Mean	3.86	4.14
Standard deviation	0.09	0.15

Table 6. Participants' responses on their satisfaction with the results on a 7-point Likert scale (1 = very unsatisfied, 7 = very satisfied)

Satisfaction with	Software	Paper
Overall quality of own ideas		
Mean	5.04	5.30
Median	5.00	5.00
Standard Deviation	1.16	0.86
Overall quality of team ideas		
Mean	5.04	5.00
Median	5.00	5.00
Standard Deviation	1.33	1.22
Own productivity		
Mean	5.17	4.61
Median	5.00	5.00
Standard Deviation	1.09	1.52
Team productivity		
Mean	5.43	5.00
Median	5.00	5.00
Standard Deviation	0.82	1.50
Feasibility of own ideas		
Mean	5.04	5.35
Median	5.00	5.00
Standard Deviation	1.23	0.91
Feasibility of team ideas		
Mean	4.65	4.87
Median	5.00	5.00
Standard Deviation	0.91	1.33
Originality of own ideas		
Mean	4.91	5.35
Median	5.00	5.00
Standard Deviation	0.93	1.20
Originality of team ideas		
Mean	5.04	5.43
Median	5.00	5.00
Standard Deviation	1.33	1.01

We looked at the previously mentioned disadvantages commonly associated with verbal brainstorming.

The problem most evident to participants was production blocking. It was explicitly described by nine of the participants as either a drawback of the paper-based version or the absence thereof as an advantage of the software version (see analysis above on the parallelization of the process, with comments "*no discussion, which allowed for clear decisions regarding the validity of each idea [...] This was more efficient*", "*complete free working with judgement of others*" [Annotation of authors: vs. "*judgement within the team and no 100% free idea flow*" about the paper based version], "*everybody could work at the same time*", "*less time per person, and didn't waste time*", "*It was easier to simultaneously collect attributes and ideas*", "*easier to parallelize*", "*no time lost for arguing*", "*more efficient, whereas if you communicate together, you really use up all the time*", "*With 6 people crowded in front of the paper canvas, it was difficult to get working, as someone was blocking the view, paper, whatever.*"). Other comments on efficiency may refer to production blocking as well but were somewhat hard to interpret.

The avoidance of evaluation apprehension through the software was mentioned by four people ("*You feel more satisfied while including any ideas even if it was not that unique*", "*easier for shy people to add their ideas*", "*anonymous*", "*judgement within the team*" (Annotation by authors: the latter on the paper-based version).

We did not observe social loafing in the paper-based session. This is most likely due to the fact that the students were selected for the study program due to a higher than average motivation. Furthermore, the ideation session directly contributed to their curricular project work. However, with the participants being anonymous in the software session, social loafing might have been an issue.

4. Summary and Discussion

In traditional group brainstorming, verbal brainstorming is preferred over electronic brainstorming, although the latter can level out several drawbacks of verbal brainstorming (such as production blocking, evaluation apprehension and social loafing). According to Dennis et al. [2], a major reason is that users are not only interested in performance-related factors but also in softer factors such as group well-being and member support which they attribute to verbal brainstorming.

Looking at the arguments provided, in line with Dennis et al., non-performance-related factors did play an important role in participants' preferences. However, we found that with the more complex method of MA, factors leading to a higher task performance or better process support were the main decision factors for preferring the software solution over the paper-based version.

As Dennis et al. found in their survey among 131 MBA students, there are common expectations that lead to the preference of verbal brainstorming over electronic brainstorming. We expect to encounter expectations also regarding software-supported morphological analysis, which, however, may prove wrong or less important than arising benefits when participants actually experience the software, as our empirical study suggests.

Interestingly, all four individuals that preferred the paper-based version were in the two teams that started with the paper-based session, whereas all participants of the teams that started with the software session preferred the software or were neutral. The underlying study was conducted with technology-affine participants of ages 20-29, who might be more open towards accepting software solutions for group tasks. Being enrolled in an add-on study program on Technology Management, their interest in technology is expected to be above average.

Also, within this study, people were highly motivated to perform the task given, as on the one hand, they were selected for the course program because of their above-average academic performance and motivation and on the other hand, the outcome of the task was directly relevant to their course work. Such a high level of motivation is not always the case in other organizational settings, which might somewhat limit the generalizability of the study.

In the case of the teams on this experiment, there was no designated team leader within the teams, so participants were on an equal level of hierarchy. Dennis et al. suggested that status is an important factor within brainstorming and is thought to be served better by verbal brainstorming. We think that members with a higher level of hierarchy within a group may indeed miss this "status auction" within an anonymous software process. However, we think that gamification mechanisms may counteract this drawback.

5. Conclusion and Future Work

Our study leads to the hypothesis that with regards to more complex group creativity processes, the employment of software can be beneficial over traditional, non-software based processes.

However, as in the case of traditional brainstorming, preconceptions regarding the benefits and/or drawbacks of creativity software vs. verbal techniques might be an obstacle to technology acceptance.

Preferences for the software session (13 participants) largely outnumbered preferences for the paper-based session (4 participants). However, the total sample size of 23 participants is relatively low. For further research, we therefore suggest a larger, quantitative study that tests the hypothesis generated within this study. In addition, comparing preconceptions with actual results after employing a software-based process may show gaps and lead to further hypotheses on how these could be bridged.

In a future study, it would be interesting to further investigate whether the order in which participants get to know a method has an impact on their preference.

This study focused on participants' subjective satisfaction. For future studies on objective performance, we suggest to include ratings by an external expert. Also, we suggest to investigate whether variability or homogeneity in acceptance influences team performance, behavior and/or group dynamics.

We also suggest further research on the main drawbacks mentioned with regards to the software (e.g. how to allow the clarification of questions on ideas, and on how to incentivize participants to build on ideas of others and to generate a sense of group belonging). In addition, elements that work well within smaller groups might not work as well in a larger group settings (e.g. open innovation processes).

In terms of practical relevance, the arguments in favor of the software solution found within this experiment may prove helpful in promoting the employment of software-based processes and in finding acceptance among decision-makers. In addition, software developers may work on addressing the current disadvantages mentioned by participants.

6. Acknowledgements

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