A Comparison of Cooperative and Competitive Visualizations for Co-located Collaboration

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ABSTRACT

We present a study that investigates the influence of different types of visualizations on collaboration. The visualizations present the group's performance either in a more cooperative or more competitive way. Decades of research suggest that cooperation leads to greater productivity than competition. However, most of the existing group mirror visualizations achieve an increase in productivity and better self-regulation by enabling a direct comparison of performance within the group. We conducted a repeated measures study with 12 groups that were supported by visualizations that displayed the number of ideas of a brainstorming session (1) per person (competitive condition) (2) per group (cooperative condition), (3) per person and per group (mixed condition) and (4) without visualization (baseline). Results indicate that groups that see a combination of individual and group performance (mixed condition) are more productive, more satisfied with their results and participate in a more balanced way.

Author Keywords
Feedback; Cooperation; Competition; Group Mirror.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

Cooperation is a crucial behavior of humans. Barnard [2] argues that the origin of cooperation comes from the biological limitations of humans that can most effectively be overcome by cooperation. While some research argues that competition can be constructive under certain circumstances [16, 26], several decades of research show evidence that cooperation increases productivity, leads to higher achievements and higher-level reasoning compared to competition [13]. Definitions and an overview of research on cooperation and competition can for instance be found in Maller [19], Deutsch [6], May and Doob [21] and Johnson and Johnson [14, 15].
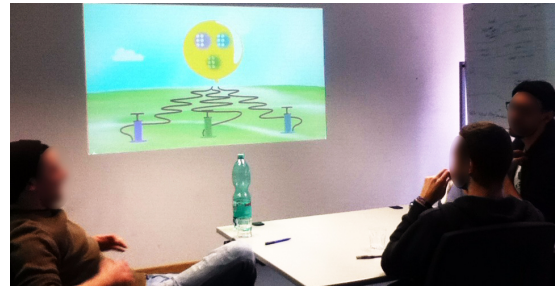
Figure 1. Study setup with the mixed visualization.

Group mirrors can help to support effective cooperation. These systems provide feedback to a group about specific aspects of their collaboration [12]. A common example is a visualization of speaking times on a peripheral display during some kind of co-located group work. These systems achieve an increase in performance and better self-regulation. However, they may also lead to frustration, social pressure and competitive behavior [1, 25, 29], as they allow group members to compare their performance to each other.

The group mirrors *Reflect* [1], *Second Messenger* [9] and *Conversation Clock* [4] enable a direct comparison of individual speaking durations. The *Meeting Mediator* [18] and a system by Sturm et al. [28] visualize speaking durations combined with other social factors such as eye gaze. *Groupgarden* [29] implements a combination of individual progress in form of flowers and group feedback in form of a tree. Again, these visualizations allow group members to compare their performance to each other. We were interested, if more cooperative visualizations have similar effects on performance without negative effects of social pressure and competition.

There is a large amount of studies in the fields of psychology, sociology, economics and anthropology that investigate the effects of cooperative and competitive reward structures on social dynamics such as social loafing or social facilitation [7, 10, 17]. Huang et al. [11] for instance showed that cooperative and competitive rewards can both improve performance of crowdsourcing when combined with the right methods of social transparency increase. Beersma et al. [3] showed that teams composed of extrovert and agreeable members profit from cooperative reward structures while disagreeable introverts benefit from competitive rewards. These results reveal potential for both reward structures. Our approach builds on this line of research as it adopts the concept of cooperative and competitive incentives and applies it to group mirror vi-

Figure 2. We compared four different metaphorical visualizations indicating the number of ideas during a brainstorming.

sualizations. Additionally, we investigate the novel concept of mixed reward structures by including a visualization that combines the cooperative and competitive concepts.

In order to gain insights into the effect of more cooperative visualizations on group processes, we ran a study in which we compared three different visualizations and a baseline: The *competitive* visualization resembles most of the traditional group mirrors as it shows the number of ideas during a brainstorming session for each participant. The *cooperative* visualization displays the overall number of ideas of the group. The *mixed* version shows both (see Figure 1). Our main purpose is to understand if cooperative visualizations can achieve the same effects as the "traditional" group mirror visualizations.

DESIGN AND IMPLEMENTATION OF A GROUP MIRROR

Based on our literature review, we explored different concepts which we evaluated in a pre-study. The emerging visualization was then discussed with a group of experts.

Initial Design Decisions & Prestudy

Streng et al. [27] suggest a classification for group mirrors consisting of (1) placement (table or wall display), (2) type of mirrored information (quantitative or qualitative) and (3) type of visualization (diagram or metaphor). We chose a *wall display*, as it is perceived as less disruptive and produces less pressure than a table display [29]. Mirroring only quantitative information is questionable [8], thus we chose to provide feedback about *qualitative data* in form of the number of ideas. This information is qualitative as not every contribution can be counted as a new idea. Lastly, we decided to use *metaphoric visualizations*, as these can lead to faster correction of unwanted behavior and is preferred by group members compared to diagrammatic feedback [27].

We evaluated four different concepts in a prestudy (see Figure 2) to find a metaphor that is easy to understand and emphasizes the differences of the three conditions. "Change of size" is realized with the metaphor of balloons that grow with the number of stated ideas, "change of amount" with marbles, "change of distance" with canoes that cover a certain distance and "change of color" with light bulbs that light up dependent on the number of ideas. All visualizations exist in three versions. In the competitive version, group members have personal representations, in the cooperative version the amount of ideas is accumulated and in the mixed version, both the individual as well as the overall progress are visible.
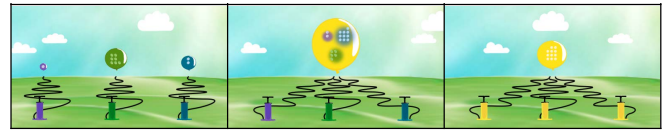

Figure 3. The competitive (left), the mixed (middle) and the cooperative version (right) are realized with the metaphor of balloons.

Results of our prestudy with 4 participants (1 female, average age 44, 2 engineers, 1 student, 1 teacher) indicate that the balloon was easiest to understand and the concepts of cooperation and competition were clearest (followed by canoe and marble). In short interviews, participants looked at the print-outs of the visualizations one after the other (counterbalanced with a Latin square). We asked how they interpreted the visualizations in a brainstorming context. In questionnaires, they stated if they could easily estimate their amount of ideas or if they would perceive the success of others as their own.

The balloon version was discussed with a group of experts (1 female, 6 male; 1 PostDoc, 4 PhD students, 2 professors of HCI, one of them with significant knowledge in Information Visualization), who remarked that the metaphor of balloons inside of a balloon was perceived as unrealistic, and due to change blindness it might be difficult to notice small changes.

Final Design and Implementation

The final design consists of air pumps and balloons (see Figure 3) that grow dependent on the number of ideas. In the competitive condition, each participant is represented with a differently colored balloon. In the mixed condition, a big balloon represents the overall number of ideas, inside of this balloon there are differently colored areas, resembling differently colored gases. The cooperative visualization consists of one big balloon representing the number of ideas of the whole group. Small dots indicate the exact number of ideas. A short animation is shown with each new idea: The correspondent air pump moves and the balloon grows.

The prototype was implemented in Objective-C in XCode and ran on an iPhone5c with the operating system iOS7. In the study, the experimenter controlled the visualization via smartphone, which was connected to a projector. To change a visualization, the experimenter had to tap on the corresponding air pump. The group could then see the changes on the wall.

DESCRIPTION OF THE EXPERIMENT

We conducted a user study to investigate, which effects different visualizations have on group processes. We were particularly interested, which visualizations improve performance and which one is most accepted by the group.

Participants

36 voluntary participants (6 female; average age 25, range: 19 to 31 years) took part in the experiment in groups of 3. Participants of each of the 12 groups already knew each other before the study. 28 were students, 5 software engineers and 2 employees in other professional fields. They could choose if they wanted to receive a 10 Euro voucher from a well-known online web-store or credits for their studies.

Table 1. Results from the linear mixed model with the cooperative condition and topic 1 as reference categories.

	Estimate	95% Confidence Intervals	p-value
Intercept	8.19	[6.38,10.00]	
Baseline	-0.44	[-1.76,0.87]	0.5097
Mix	1.86	[0.54,3.18]	0.0065
Competitive	-0.08	[-1.40,1.23]	0.9015
Topic 2	-0.03	[-0.83,0.78]	0.9463
Topic 3	-0.67	[-1.47,0.14]	0.1078
Topic 4	-0.50	[-0.31,0.31]	0.2267

Method and Procedure

The study took place in a quiet room equipped with a rectangular table and a projector. Participants sat around the table so that each person could see the visualization as well as each other. The projection surface measured 1.6m x 3.2m.

The study was designed as a within-groups experiment. Participants were asked to conduct four brainstorming sessions that each lasted 8 minutes. The condition without visualization served as a baseline, in the other three sessions the different visualizations were shown on the wall. Groups were given four different topics: (1) ideas for an app supporting sports and fitness, (2) supporting healthy nutrition, (3) ideas for an app for children and (4) ideas for an app for planning a journey. We therefore had 4 conditions and 4 topics that we counterbalanced using a Latin square design, consequently each combination occurs only once in each round.

Before the brainstorming, the following brainstorming rules were explained to the groups: (1) quantity before quality, (2) wild ideas are welcome, (3) build on ideas of others, (4) stay on topic and (5) do not judge ideas of others [23]. We asked groups to follow these rules, implying that one of their goals was to find as many ideas as possible. We did not ask them to strive for balanced participation. We intentionally did not provide any additional incentives such as rewards or bonus payments in case a group or group members outperform others, as the main purpose of the study was to investigate the effects of the visualizations on groups.

Before each session, the corresponding visualization was explained. After each session participants had to fill out a questionnaire. The study ended with a final questionnaire about demographics and a comparison of the three visualizations.

During the sessions, the experimenter listened to the discussion and increased the idea counter when someone stated a novel idea to update the visualization. To diminish the chances that this estimation is arbitrary, two coders rated all sessions of the first group independently during the study. We defined an idea as (1) an on-topic contribution that has not been stated by someone else and (2) that, if it builds on an already stated idea, creates a new facet of this idea. Afterwards, the two coders watched the video recordings to count the contributions that they did not classify as an idea. Cohen's kappa showed substantial agreement ($\kappa = .66$).

The study was video- and audio-recorded. One video camera was positioned in front of the group, one in the back. The number of ideas was logged together with a time stamp and the ID of the person. Pen-and-paper questionnaires were handed out about demographics and opinions to the system.
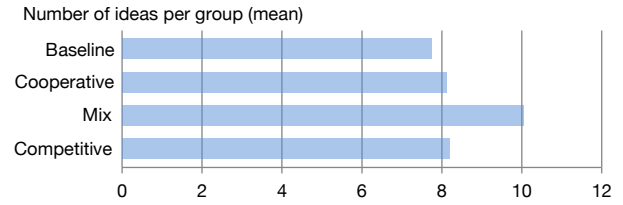

Figure 4. Participants stated the most ideas in the mixed condition.

RESULTS & DISCUSSION

We discuss qualitative data collected from the answers from the questionnaires and quantitative data reporting results using a linear mixed model with condition and topic as fixed effects and groups as a random intercept, using dummy coding for condition and effect coding for topic. For the analyses we used the statistical software R. The model was fitted using the lme function from the package nlme [24].

Performance

Results from the linear mixed model show that the average number of ideas per participant was 7.75 in the baseline, 8.19 in the cooperative, 10.05 in the mixed and 8.11 in the competitive condition (see Figure 4), with a significant difference between the mixed condition and the other conditions (see Table 1). This indicates that the mixed version was more beneficial for productivity and motivation than the others.

As a measure of the goodness of our model we compared the residual variance between our final model and a model which only included the group effect as random intercept without any covariables. The residual variance in the full model is 8.13 (variance of random intercept: 7.46), whereas the variance in the null model is 9.22 (7.27).

Balance of Participation

Results indicate that participation is most balanced in the mixed condition. We used a variation of the Gini coefficient [30] to calculate balance. Several researchers have developed a measurement for participation rates based on this coefficient [9, 20, 30]. The resulting value reaches from 0 to 1 (0: perfectly balanced). We adapted the equation for a group of 3 people:

Balancing index (BI) = $\frac{4}{5} * \sum_i |participation_i - 33\frac{1}{3}\%|$

Our results suggest that participation (in our case number of ideas) is more balanced in the mixed condition (BI=0.56) compared to all other conditions (Baseline and Competitive: BI=0.61, Cooperative: BI=0.6). This shows that the increase in performance can be attributed to the whole group, not only to individual participants.

Motivation, Productivity & Pressure

Results from the questionnaires are depicted in Figure 5. The competitive visualization was rated as most motivating (22 agreed/strongly agreed), closely followed by the mixed version (21). Similar answers were given for productivity (17 for the competitive, 16 for the mixed). The competitive version was perceived to generate more pressure (16) than the other two visualizations (cooperative: 8, mix: 12). Not very surprisingly, the cooperative visualization was rated to produce
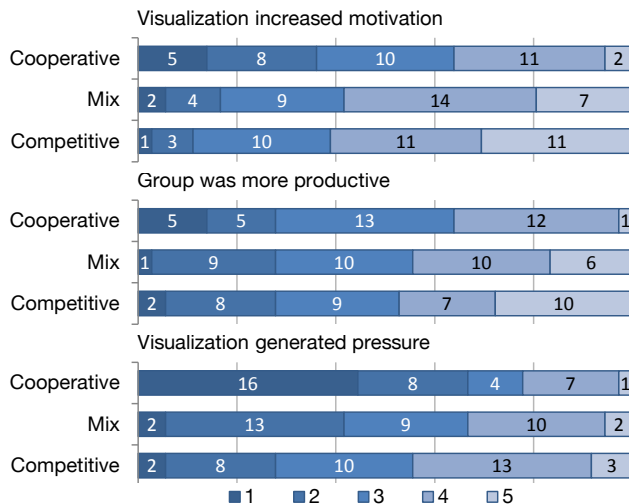
Figure 5. Results of 5-point Likert scales addressing motivation, productivity and pressure (1:strongly disagree, 5:strongly agree).

Figure 6. Votings for one modality regarding different aspects.

pressure by the least. The individual responses to these questions do not correlate within groups. Interestingly, the competitive visualization was perceived most motivating while the quantitative results point in another direction. This might be due to the perceived pressure, which might reduce the positive effect of increased motivation [5].

Qualitative results

In the final questionnaire, we asked participants to vote for a specific modality (see Figure 6). We first asked, which visualization they liked best ("General preference"). 17 preferred the cooperative one. Reasons were that "*the collective idea generation strengthened the team spirit*", (G1P2) that a "*joint goal*" means "*enjoying teamwork*" (G5P2) and that it created "*no pressure, therefore much better working and free thinking*" (G12P3). Similarly, 16 preferred the mixed condition. Participants liked the combination of the visualization of the common goal which still makes it possible to compare each other: "*You were integrated in the group but at the same time encouraged to contribute*" (G7P2).

We also asked participants with which visualization they felt most comfortable ("Feeling comfortable"). Most answered in favor of the cooperative one (26), 8 voted for the mixed visualization, the rest mentioned several or none. Reasons for choosing the cooperative visualization were that there was "*less pressure*" and a "*relaxed atmosphere*".

Finally, we wanted to know with which visualization people were most satisfied with their performance ("Performance"). 13 answered that this was the case in the mixed condition, mostly because they perceived the whole group as more productive. One stated it was "*because I had a larger idea-area compared to the others*" (G1P3). 9 named the competitive, as they liked the competitive character, however for 5 participants the topic was the reason (3 times travelling, 1 sports, 1 nutrition). 8 were most satisfied with their performance in the cooperative modality. Some said that they had good ideas and that they liked the appreciation of their ideas. One person wrote: "*Maybe nobody noticed my failure? :)*" (G2P3).
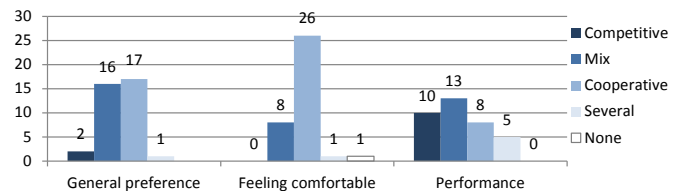
These results indicate that the traditional concept of group mirrors, displaying only individual performance, can be enhanced by providing the group with a representation of the common goal. Another implication is that context and goal matters: If the main goal of collaboration is to be most productive, and the group itself is not in the focus, a visualization displaying individual and accumulated progress might be the best choice. In a setting where it is important for a group to feel comfortable, e.g. when a group is newly formed, a cooperative visualization might be more appropriate.

An explanation for these results could be that people with different personality traits react differently to the visualizations. Both the cooperative and the competitive visualization might be beneficial for people with a specific personality, but less effective for others. This assumption is in line with the results of Beersma et al. [3], who could show that more agreeable and extrovert people profit from a cooperative reward structure, while disagreeable introverts benefit from competitive structures. The mixed visualization might accumulate these effects, leading to an overall increase of performance.

SUMMARY & FUTURE WORK

We presented the first study comparing the concept of prevalent group mirrors that mostly display individual performance with a more cooperative concept. In summary, the results suggest to use a mix of individual and accumulated representations when designing group mirrors. 34 participants preferred either the mixed and/or the cooperative visualization, while only 2 preferred the competitive visualization. With the competitive version, groups felt more productive, however they also felt the least comfortable and the most pressured. Also, performance and balance of participation were similar to the baseline. Hence, the combination of individual measurements with a visualization of the common goal was a good trade-off: Participants felt satisfied with their performance, produced most ideas and participation was balanced.

For future studies, it would be interesting to investigate different personality traits in the context of group mirrors. It would furthermore be of value to test groups in which participants do not know each other, or larger groups. In smaller groups, there is more individual accountability [22], so maybe there is more need for competitive visualizations in larger groups to achieve the same performance increase.

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