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Tackling Information Overload in Electronic Brainstorming

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Abstract

Electronic brainstorming allows users to generate ideas in parallel to mitigate production blocking, but, on the other hand, this increases the cognitive load on the users and may cause information overload. We address this trade-off by leveraging the users' natural alternation between generating ideas and attending to new ideas by others to manipulate the delivery timing and quantity of ideas that users are exposed to. Results from a laboratory experiment indicate an improvement of 9.6% in the number of ideas produced by groups compared to the immediate delivery of ideas.

1. Introduction

Studies on brainstorming in the Group Support Systems (GSS) research area have traditionally compared group performance with and without technological support. Several experiments have measured, e.g., the effectiveness and efficiency of the idea generation process in face-to-face meetings versus using GSS in a wide array of conditions such as group size, proximity, and composition, number of sessions and session length, and others [Fjermestad 1999].

Brainstorming is one of the most studied group tasks and this has enabled the identification of factors that drive the motivation gains and losses during the creative process [Shaw 2002, Nunamaker 1991]. Technology, namely electronic brainstorming, has addressed some of these loss factors by allowing users to remain anonymous to mitigate evaluation apprehension and by letting users submit ideas in parallel (instead of serially as in group turn-taking) to attenuate production blocking [Hymes 1992].

However, the use of electronic brainstorming may create new conditions that induce process losses, which emphasises the need to further explore and compare technological options to find out which of them allows groups to be more productive. This is especially important in today's world because organisations rely ever greater on distributed work settings.

The work we present in this paper addresses *information overload*, a process loss that may occur during brainstorming sessions because technology allows users to submit ideas in parallel. Our approach is to manipulate the computer-controlled delivery mechanisms that expose users to the ideas generated by the group, inspired by cognitive factors that may influence user performance in electronic brainstorming sessions. This is something that, to the best of our knowledge, has not been reported in the GSS literature.

In Section 2 we show empirical motivation for providing technological support for the characteristic alternation between the individual generation of ideas and paying attention to the other users' ideas, and present an electronic brainstorming tool that manipulates the delivery of group ideas to the users. In Section 3 we describe a laboratory experiment to compare group performance under the influence of two idea delivery mechanisms, whose results are discussed in Section 4. We conclude the paper in Section 5 with a summary of contributions and plans for future work.

2. Addressing Information Overload

The rules of brainstorming [Osborn 1963] encourage users to perform two main cognitive tasks: the first is to produce as many ideas as possible, because quantity is wanted; and the second is to read, or at least look at, the other users' ideas, because combination and improvement of ideas is sought.

In electronic brainstorming users can submit ideas in parallel, which puts more effort in the second cognitive task. As the number of ideas increases, e.g., because the group is inspired or group size is large, users may no longer be able to process the flow of new ideas, and may even become distracted by it, thus causing information overload.

To tackle this problem we set out to understand how users work during electronic brainstorming sessions. To this end we developed an instrumentalised brainstorming tool with built-in sensors of user performance and asked groups of five volunteers to simulate a distributed work setting by only using the tool to communicate, i.e., no face-to-face interaction was al-

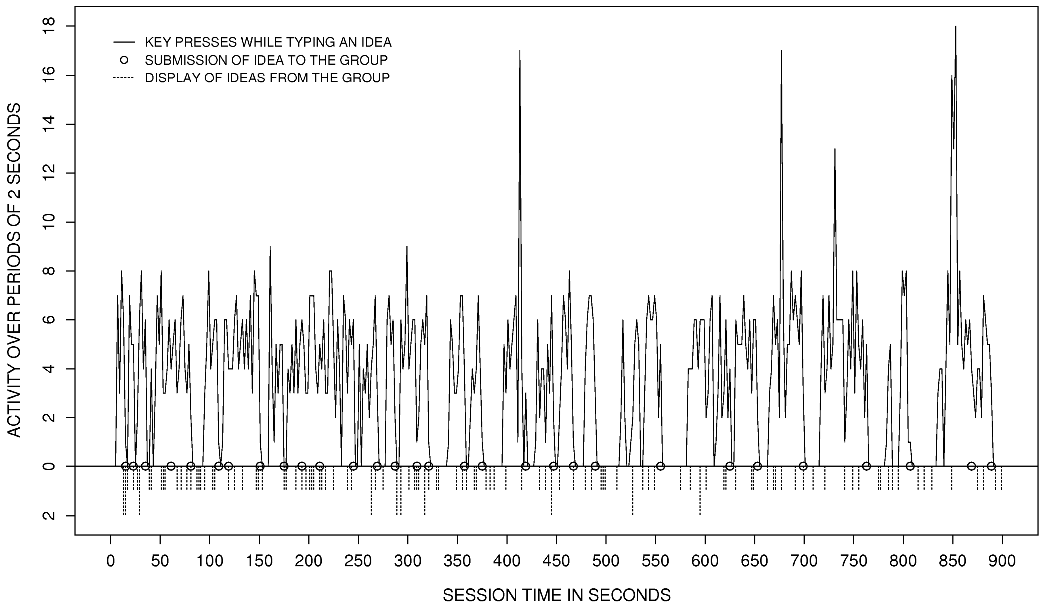


Figure 1. User and group activity during a brainstorming session, with immediate delivery of ideas to everyone on the group. Above the X-axis are aggregated counts of user key presses. The spikes occurred when the user pressed the delete or cursor keys. The circles on the X-axis show when the user submitted the idea s/he was typing to the group. Below the X-axis are the instants in time when the user received new ideas by the other users.

lowed. We recorded three types of events: a) user key presses while typing ideas; b) the moments when the user submitted an idea to the group; and c) the instants when group ideas were delivered to the user's computer display.

Figure 1 shows a sample of the data we obtained and illustrates the results for an entire fifteen minute session, in which 152 ideas were produced. From the evidence we collected, three patterns emerged: first, users usually do not stop typing when they receive ideas from the other users and, thus, we assume that they continue focused on the individual task of generating ideas; second, users typically pause after putting forward an idea, presumably to keep up with the group; and third, we found numerous periods of time with no typing activity (not shown in Figure 1) but we could not tell if they were because of lack of imagination or due to free riding (users relying on others to do the work) [Nunamaker 1991].

These patterns of user behaviour may not provide enough evidence that users are overloaded with information, but they do tell us that users have a natural tendency to alternate between generating ideas and paying attention to the other users' ideas. Thus, we assume that if users are exposed to a greater number of ideas they will continue to attend to them after finishing typing their own idea. This assumption led us to the concept of automatically manipulating the delivery *timing* and *quantity* of ideas that are presented to each user based upon the user predicted state of attention.

In this new way of mediating brainstorming sessions, the computer defers the presentation of group ideas until the user is likely not typing an idea, which may be just after a submission or after a period of inactivity. Moreover, a limit is enforced to the quantity of ideas delivered at each occasion if the rhythms of the user and the group differ too greatly, to avoid overloading the user. In other words, instead of receiving one idea at a time as soon as it is generated, possibly at a very fast rate, the user processes small *batches* of ideas collected over time.

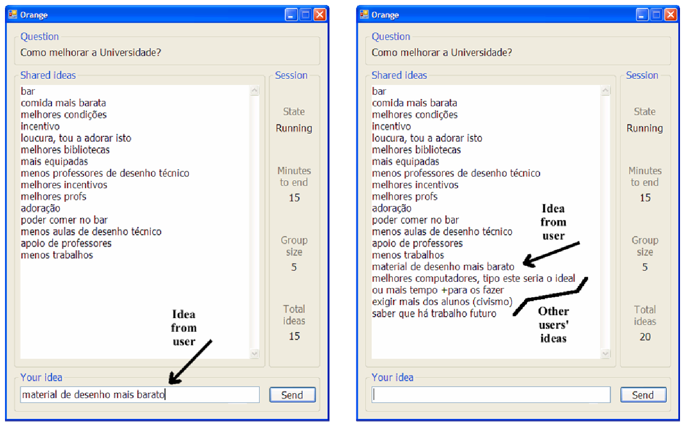


Figure 2. Brainstorming tool manipulating the delivery of ideas. *Left:* while typing an idea, the user receives no new ideas from the group. *Right:* when the user submits an idea, recent ideas from others, collected in a small batch, are displayed.

Figure 2 shows two screenshots of the same instrumentalised brainstorming tool that we referred to earlier, now working in the new mediation mode. More details about this tool, including its architecture, design, and implementation, can be found in [Ferreira 2007].

3. Laboratory Experiment

We now describe a laboratory experiment that we set up using our brainstorming tool to test the hypothesis that group performance—measured in number of ideas produced—increases when groups are exposed to the proposed idea delivery mechanism.

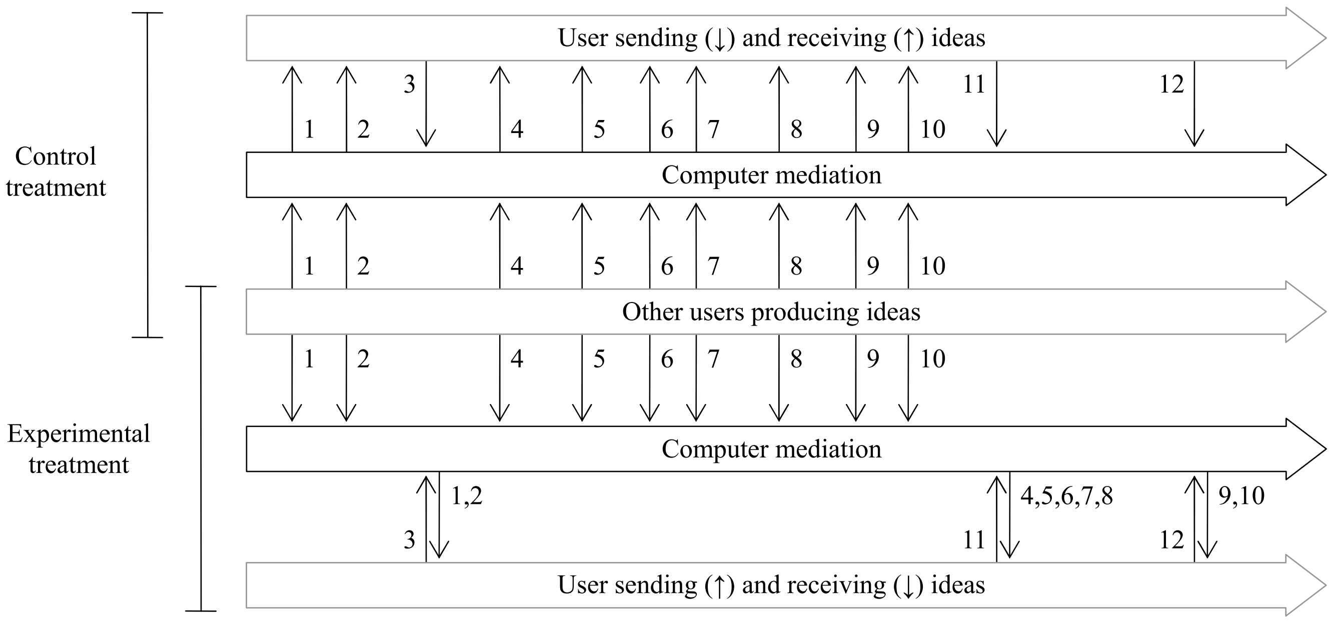


Figure 3. Simulation of group and user activity under the control and experimental treatments. In both cases the user produces three ideas (numbered 3, 11, and 12) but the exposure to the nine ideas s/he received from the other users is different.

Another metric for group performance could be the quality of ideas but this is harder to assess and compare, and there is evidence that it is positively linked to quantity [Briggs 1997].

3.1 Treatments

Two treatments were devised for the experiment: in the *control* treatment group ideas were immediately delivered to all users as soon as they were generated; the *experimental* treatment corresponds to the proposed way of manipulating the delivery of group ideas to the users.

Figure 3 illustrates the differences between the two treatments in a simulated brainstorming session, from which we highlight that under the control treatment the user immediately received all nine ideas generated by the group in contrast with three batch deliveries of ideas under the experimental treatment.

Two parameters were configured for the experimental treatment: the maximum number of ideas per batch was set to ten (in Figure 3 the batch size is five ideas), and the period of inactivity after which we assume the user is not concentrated in typing an idea was set to ten seconds.

3.2 Participants

A total of 11 groups of 5 people, for a total of 55 volunteers (44 men and 11 women) participated in the experiment. The median age was 23 years (minimum 20 and maximum 29). 51 participants were students (40 undergraduate, 10 MSc, 1 PhD), and the remaining 4 comprised researchers, a software developer, and a translator.

A convenience sampling was used to select participants, who were recruited from social contacts and posters on corridors at the University of Lisbon. No monetary reward was offered and the only information available was that the experiment would concern brainstorming.

A self-assessment of typing experience with computer keyboards, in a three-point rating scale, revealed that participants were skilled (86% chose the highest score) and the remaining 14% chose reasonable experience.

3.3 Apparatus

The experiment was conducted in a laboratory room having five laptops with identical hardware and software specifications, interconnected by a dedicated wired-network. Keyboard sensitivity, desktop contents, display resolution, and brightness were controlled. Our instrumentalised brainstorming tool was installed on all five laptops.

3.4 Task

Participants completed practice and test tasks, both related to brainstorming. The *practice* task allowed participants to get familiar with the brainstorming tool. In the *test* task, participants were given a question, selected from a known list [Shaw 2002], and then asked to generate as many ideas as possible, by typing on the keyboard and by looking at the computer display. Speech or other forms of communication were disallowed to simulate a distributed work environment.

3.5 Design

A repeated measures design was chosen for the experiment. The independent variable was *mediation mode* with levels corresponding to the control and experimental treatments illustrated in Figure 3. The dependent variable, *group performance*, was calculated from the sum of the number of ideas produced by the users on the group.

Table 1. Session order/brainstorming question per group and treatment. The questions were: A, how to preserve the environment; B, how to attract more tourists to Portugal; C, how to improve the university; and D, how to stimulate the practice of sports.

	Groups										
	1	2	3	4	5	6	7	8	9	10	11
Control	1/C	2/D	4/C	3/B	1/B	1/A	2/C	3/B	2/B	3/C	1/A
Experimental	3/B	1/A	2/B	4/C	3/C	2/B	3/A	1/C	1/C	2/A	3/B

Table 2. Number of ideas per group and treatment.

	Groups											
	1	2	3	4	5	6	7	8	9	10	11	Total
Control	152	83	133	91	264	77	48	53	66	104	70	1141
Experimental	192	108	113	117	258	77	68	61	76	116	65	1251

The order of exposure to the treatments and the brainstorming questions used with the 11 groups are depicted in Table 1. We note that, sometimes, session order is greater than two and that four questions were used, because we are reporting here a part of a larger experiment with two additional treatments.

3.6 Procedure

A trial started when a group of participants arrived at the laboratory room. An introduction to this research was given and participants were informed on their privacy rights and asked to sign a consent form. Next, participants filled in an entrance questionnaire about gender, age, occupation, and typing experience with keyboards. Written instructions on the rules of brainstorming and on the computer tool were then handed in to all participants and read out loud by the experimenter.

Participants were asked to carry out the practice task for 5 minutes, after which questions, if any, were answered. The group then performed the test tasks in succession, each lasting for 15 minutes, with a brief rest period in between.

At the end of the trial, answers were given to the questions participants had about this research, comments were annotated, and the experimenter gave thanks in acknowledgement of their participation in the experiment.

4. Results

Results are organised in three parts: we start with an analysis of overall group performance, which is central to our research hypothesis; we then decompose group performance over consecutive periods through the duration of the brainstorming sessions; finally, we present the results of a *post-hoc* analysis based upon more fine-grained data.

4.1 Group performance

Groups produced an average of 10.0 additional ideas per session (*SD* = 17.2), +9.6%, when under the exposure of the experimental treatment (*M* = 113.7, *SD* = 60.8) than when under the control treatment (*M* = 103.7, *SD = 62.0*), corresponding to a total of 1251 ideas in all sessions versus 1141 (see Table 2). Figure 4 further shows that the difference between treatment medians was 25 ideas per session (108 vs. 83).

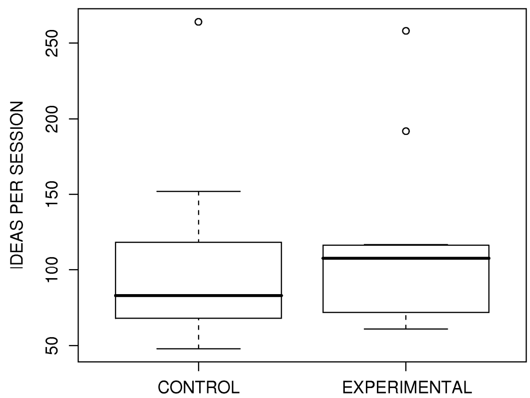


Figure 4. Group performance under the control and experimental treatments.

The Shapiro-Wilk normality test indicated that both data distributions differed significantly from a normal distribution. Therefore, we applied the non-parametric Wilcoxon signed-ranks test to the data, which revealed a statistically significant 3.7% probability of *chance* explaining the difference in group performance, $W_+ = 45.5$, $W_- = 9.5$.

We also analysed possible confounding influences from the questions or session order on group performance to see if there was a bias introduced by popular questions or a learning effect due to the nature of the repeated measures design. In both scenarios the Wilcoxon signed-ranks test found no statistically significant influences: $p > 0.205$ and $p > 0.343$, respectively.

Given this evidence, we can accept the hypothesis that group performance in distributed electronic brainstorming tasks improved when groups were under the experimental treatment, i.e., the experiment shows that by manipulating the delivery timing and quantity of ideas that users are exposed to allows the group to produce more ideas.

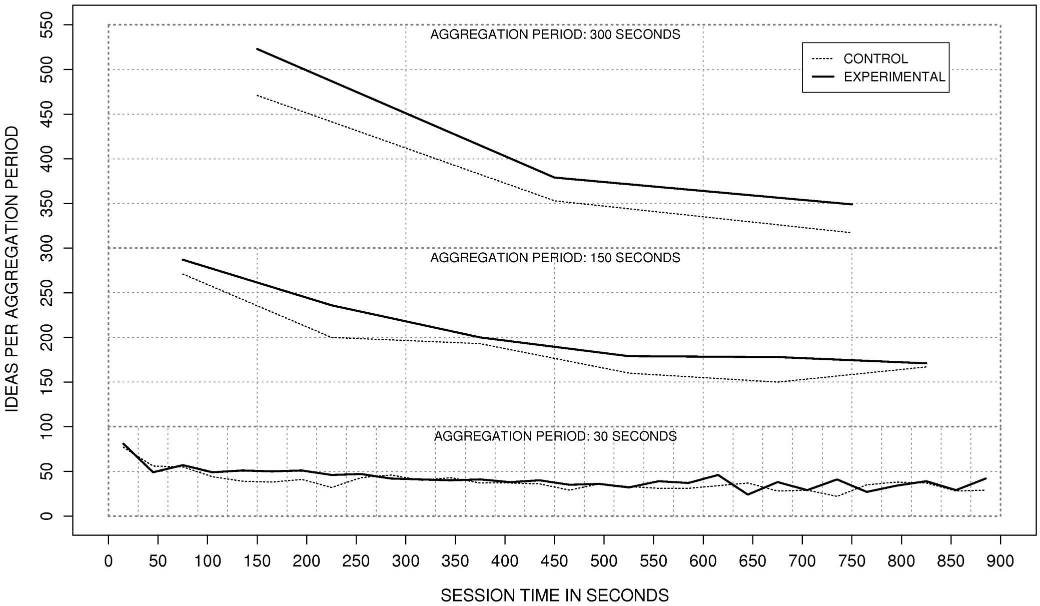


Figure 5. Group performance through the duration of the brainstorming sessions under the control and experimental treatments. *Top:* number of ideas per period of 300 seconds. *Middle and bottom:* same, considering periods of 150 and 30 seconds, respectively.

4.2 Group Performance over Time

We analysed group performance through the duration of the brainstorming sessions by breaking down the 900 seconds that every session lasted into consecutive periods of 300, 150, and 30 seconds, and counted the number of ideas put forward during each period.

By using this approach we intended to highlight specific periods, if any, when one of the treatments would enable better group performance. For example, a brainstorming session may be separated into at the beginning (when users usually have plenty of ideas), at the middle, and at the end (when users typically are more passive).

This division of a brainstorming session in three phases is depicted in the top region in Figure 5, which shows that in all three periods of 300 seconds groups produced more ideas under the experimental treatment. This outcome is reinforced by similar results in the 150 seconds periods (see middle region in Figure 5). Finally, if we consider the count of ideas collected over periods of 30 seconds (see bottom region in Figure 5) then group performance under the experimental treatment is better in 21 out of 30 cases than under the control treatment.

We do not provide descriptive statistics for this type of analysis because its meaning would be attached to the choice of periods, which depends on the context. Instead, we note that there seems to be no particular phase in which results under the experimental treatment could be considered worse in comparison with the control treatment.

4.3 Post-Hoc Analysis

We also performed a *post-hoc* analysis based upon the data that we collected with our instrumentalised tool to characterise the actual delivery of ideas, as well as, the performance of the users and groups during the brainstorming sessions. The variables we considered are: DLVR, number of deliveries of ideas per session; TBDL, seconds between consecutive deliveries; PAUSE, seconds between a user submitting an idea to the group and restart typing; TIDEA, seconds to write an idea; CIDEA, characters per idea; CHARS, total number of characters typed per user in a session; DCHARS, total characters deleted per user per session; and, finally, DISCR, a measure of the discrepancy between the number of ideas produced by the users within the group[1], which serves as a candidate indicator of free riding.

Table 3 shows a summary of the results we obtained, including descriptive statistics and the output of the Wilcoxon signed-ranks test, which we use in this paper to prioritise the presentation of further details rather than to do null hypotheses significance testing. Thus, no family-wise corrections were made.

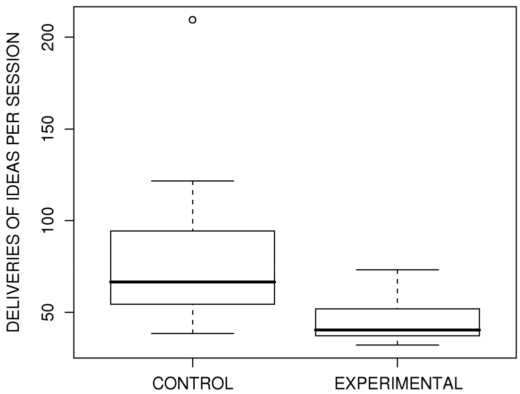
Starting with the DLVR variable, the experimental mediation mode reduced by an average of 44.1% the number of deliveries of group ideas that reached the user per session (more details are shown in Figure 6a). This difference was due to each delivery having comprised a batch of 1.9 ideas on average (*SD* = 1.2), with up to 5 ideas in 99% of the cases, unlike the control mediation, in which new ideas were immediately broadcasted, one by one, to the group.

1 We used the following algorithm to calculate DISCR: 1) sort the number of ideas produced by the users; 2) add the differences between consecutive pairs of values, e.g., ($1^{st} - 2^{nd}$) + ($2^{nd} - 3^{rd}$) + …; 3) divide by the total number of ideas produced by the group; and 4) multiply by 100. The range of values for DISCR is 0, when all users produce the same number of ideas, up to 100, when only one user produces all the ideas (maximum discrepancy within the group).

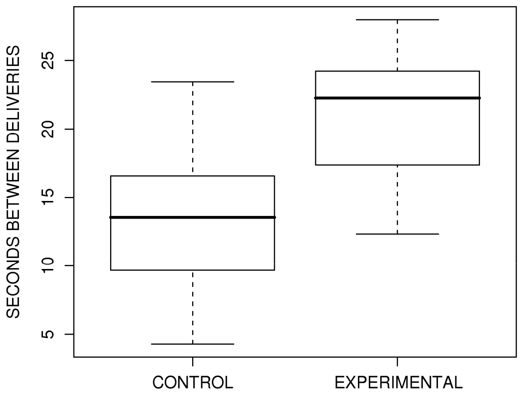
Table 3. Results of post-hoc analysis, ordered by p-value.

	Control (CT)		Experimental (EX)		Difference (EX−CT)		Wilcoxon signed-ranks test		
Variable	M	(SD)	M	(SD)	M	(SD)	W_+	W_-	p
DLVR	82.7	(49.1)	46.2	(13.6)	−36.5	(37.3)	0	66	0.001
TBDL	13.6	(5.8)	20.8	(5.2)	7.2	(2.2)	66	0	0.001
PAUSE	26.8	(11.9)	23.6	(10.3)	−3.3	(4.6)	9	57	0.032
TIDEA	22.7	(8.6)	19.4	(6.4)	−3.4	(4.9)	11	55	0.054
CHARS	1044.8	(306.3)	1110.4	(318.0)	65.6	(145.4)	50	16	0.147
DISCR	21.4	(6.1)	18.8	(7.7)	−2.6	(5.0)	17	49	0.175
CIDEA	45.1	(10.2)	43.8	(10.5)	−1.3	(4.6)	19.5	35.5	0.443
DCHARS	206.7	(78.9)	199.3	(60.4)	−7.4	(51.8)	28	38	0.700

Another consequence of the experimental mediation mode, captured in variable TBDL, is that users had 53.3% more time, on average, to think about and type ideas without receiving new ideas from others (see Figure 6b).



(a)

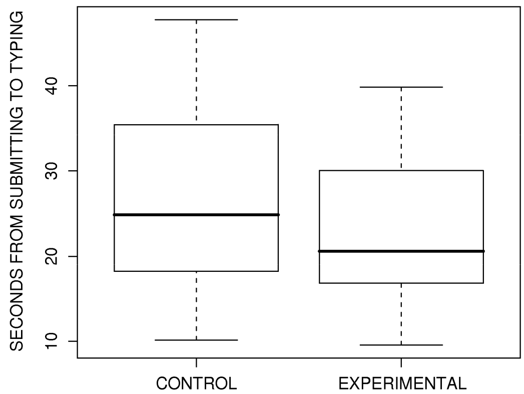


(b)

Figure 6. Characterization of idea deliveries under the control and experimental treatments.

The mediation exerted by the computer under the experimental treatment trades up-to-date broadcasts of new ideas for less frequent deliveries of batches of ideas. This could have aggravated the alternation between generating ideas and attending to other users' ideas if, for instance, users had slowed down because of the apparent delays in group activity or had become overloaded by the quantity of ideas in the batches.

In fact, variable PAUSE reveals that when under the experimental treatment, users switched 12.2% more rapidly, on average, from submitting an idea to the group to start typing the next idea, presumably reading ideas from others in between (see Figure 7a and motivation near Figure 1). We also found that in the same circumstances users needed a mean value of −14.8% of time to type an idea (see Figure 7b).



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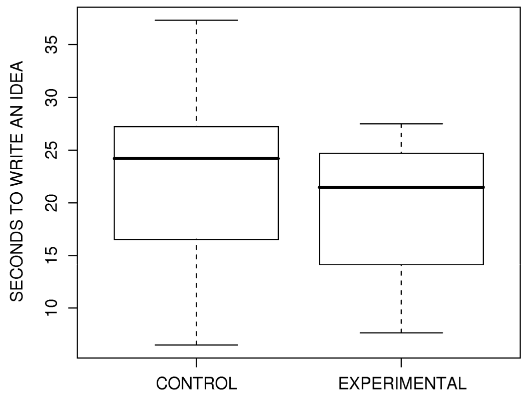

(b)

Figure 7. Aspects of user performance under the control and experimental treatments.

This evidence suggests that the experimental mediation mode contributes to better group performance in electronic brainstorming sessions by leveraging the users' natural rhythms for doing task-switching to manage the delivery of ideas.

Regarding the remaining variables in Table 3, results revealed small differences between the control and experimental treatments, thus likely explained by chance. The number of characters typed per user in a session, CHARS, was 6.3% higher, on average, in the experimental mediation mode, influenced by the higher number of ideas produced (recall Figure 4), but balanced by slightly smaller ideas (CIDEA had a mean difference of −2.9%). The number of deleted characters, DCHARS, was 3.6% lower under the experimental treatment, on average.

Finally, the production discrepancy within groups, DISCR, was 12.1% lower, on average, when groups brainstormed under the experimental treatment. This could have suggested that the experimental mediation mode mitigates free riding, had the Wilcoxon signed-ranks test not revealed a high 17.5% probability of chance explaining the difference.

5. Conclusions and Future Work

We highlighted the need to address information overload in distributed electronic brainstorming, a process loss that may occur because technology allows users to submit ideas in parallel, which may exceed our information processing capacity.

We made the following contributions to the GSS area: first, we showed that there is a natural tendency for users to alternate between producing ideas and attending to new ideas by other users; second, we developed an electronic brainstorming tool that manages the delivery timing and quantity of ideas that users are exposed to according to each user's predicted state of attention; third, we provided evidence that the proposed computer mediation mode increased by 9.6% the number of ideas produced by groups.

In addition, results from a *post-hoc* analysis revealed that the number of deliveries of group ideas that users were exposed to was reduced by 44.1% and that this translated into 53.3% more time to think about and type ideas without receiving new ideas from others. In these conditions, users were 12.2% faster in alternating between typing an idea, which they did in 14.8% less time, and attending to the group.

We believe that the technological aid we propose in this paper provides several benefits for today's and tomorrow's demands: on the one hand, even if the users in our experiment were not affected by information overload, the number of ideas produced was, nonetheless, higher; on the other hand, this technology facilitates the creation of distributed electronic brainstorming sessions with larger group sizes because it ensures that each user will be exposed to new ideas from others at his or hers own natural rhythm, thus automatically mitigating information overload.

As for future work, we are considering several research paths: one is to transfer the technology we presented in this paper to other types of group tasks, such as instant messaging; another path is to analyse videos that we captured during the brainstorming sessions to assess our assumptions about the users' focus of attention in this context, so far based solely upon activity logs; in addition, we have plans to gather more fine-grained data (compared to video analysis) by introducing an eye-tracker in future experiments.

6. Acknowledgments

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