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Exploring Asynchronous Brainstorming in Large Groups: A Field Comparison of Serial and Parallel Subgroups

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Response to the editor and reviewers for revision 2

Editor:

1. As noted by Reviewer 1 please try to make a better connection to the HFC. An example or two might help. See Reviewer 1 second paragraph to get some ideas.

We have included a few additional examples in the introduction. Further, we have included a comment in the background that collaboration technologies like Group Support Systems make longitudinal, continuous collaboration possible and we have included a reference to a study on a Navy command ship to that effect. Finally, we have reiterated in the discussion section that GSS are technological enablers of collaboration in very large groups consisting of asynchronous subgroups.

2. Reviewer 3 essentially wants you to address: (a) how the elaboration measure was conceptualized and measured and (b) how the data for the serial and parallel teams were measured and represented. These are the two big ones. This reviewer also wants you to tone down your conclusions. See this reviewer's comment #'s 7, 8, 10 and 11. These are the four needed resolutions which are summarized as mainly (a) and (b) above. But, as you know, these four need responses, clarifications and need to be dealt with in the text.

We have addressed Reviewer 3's concerns in a number of ways:

1. We have explained that we did not have the opportunity to collect data on other theoretical mechanisms during the time of the study. We argue that our results are nevertheless important as the phenomenon of asynchronous brainstorming groups has received no attention in the literature as far as we know. We call for future research into the underlying theoretical constructs in our conclusions.
2. We have explained in the response and in the paper that elaborations are not encouragements for discussion. They are just task relevant references to previous ideas. They may or may not stimulate further discussion.
3. We have explained how and why we incorporated the initial serial groups in our analysis. See response to reviewer 3.
4. We have explained that the differences in N and descriptive data in table 1 were due to unfortunate errors that we made in the earlier version.
5. Finally, we have toned down our conclusions by removing the discussion on guidelines for a combined serial-parallel approach.

We sincerely hope that we correctly understood and addressed all concerns. Below, we provide a detailed response to each of Reviewers 1 and 3's comments.

Reviewer 1:

Unfortunately, I fail to see the full application of this research to the human factors (HF) community. Within the introduction, the authors attempt to make a connection to HF by using a "24/7 crisis response task force" as an example. However, a reference to a group or team working in a complex environment, whether technological or otherwise, was not discussed again. The groups used in this study were not teams typically studied in HF. When I read about GSS in the background section, again I thought that maybe this research was tied to HF, for example how GSS impacts how teams perform. This topic was marginally mentioned throughout the remainder of the paper and no measures were used to elicit participant responses. While some participants provided feedback regarding use of the GSS (e.g., it hindered discussions), there was no discussion of the implications of using such a system.

We have included a few additional examples in the introduction. Further, we have included a comment in the background that collaboration technologies like Group Support Systems make longitudinal, continuous collaboration possible and we have included a reference to a study

on a Navy command ship to that effect. Finally, we have reiterated in the discussion section that GSS are technological enablers of collaboration in very large groups consisting of asynchronous subgroups.

Page 6, first full paragraph: second to last sentence is not necessary. The progression in a paper from the hypotheses to design and results would be obvious to the reader.
In response to comments #6 and #11 from Reviewer 3, the mentioning of tentative meeting design guidelines has been removed from this paragraph. In the re-write, the second to last sentence has been embedded.

Page 22, line 2: "different" should be "difference"
This has been corrected.

Reviewer 2:
No action was required regarding reviewer 2's feedback.

Reviewer 3:
6. On p.6, the authors note that the contributions of this work are to quantify the effects of work mode and to "develop design guidelines" for brainstorming teams. It is certainly important to note the applied implications of one's research, but isn't developing design guidelines a bit imprudent based on the results of one empirical study? See comment #11 below.
The reviewer is correct that the recommendations go beyond the data. We decided to remove the combined serial-parallel approach discussion.

7. The theoretical rationale (on pp. 7-9) for the predictions (on p. 10) are unclear. On p. 9, the authors state three reasons for why Relay teams should out-perform Decathlon teams. In brief, the authors state that, first, Relay teams may experience more synergy. Second, they imply that relay teams can work more quickly. Third, they argue that Relay teams have the opportunity for greater social comparison, which could reduce social loafing and improve performance. However, none of these arguments are ever directly assessed. For example, the authors argue that in Relay teams, the opportunity for social comparison should lead to less social loafing, thus increasing performance. Because this is a primary prediction, would it not be reasonable to assess social loafing? In this way, if Relay teams do not achieve higher productivity scores, the researcher is able to investigate the most obvious reason why this would be the case—because the proposed mechanism, social loafing, may or may not have been reduced. Without measuring the theoretical mechanisms that are proposed, we are left with the conclusion, as we have here, that there is no significant difference in overall productivity between Relay and Decathlon teams, but we don't really know why.

I still have concerns regarding this point. The point is that the authors have to explain their reasoning for why serial teams may realize some performance advantages. What they have done is remove the "theoretical model" and have made this discussion of the explanatory mechanism a bit more subtle. However, the point still stands, and this problem simply weakens this manuscript: Without measuring the theoretical mechanisms that are proposed, we are left with the conclusion, as we have here, that there is no significant difference in overall productivity between Relay and Decathlon teams, but we don't really know why. The authors state that process measures "were not available to us," but I am not sure what that means.
Our research represents a first exploratory field study into brainstorming in asynchronous subgroups. We acknowledge that we cannot provide data on the underlying theoretical

mechanisms that are discussed in the background section of the paper. This is what is meant with "process measures were not available to us". We were not able to collect any data related to the theoretical mechanisms from the groups that were part of this research study due to restrictions in access to the study's participants. Furthermore, given the exploratory nature of this research – we believe this is the first time that different asynchronous brainstorming modes were studied in the field – we decided to focus on getting an understanding of the effects of brainstorming mode on productivity first to see what kind of effects would emerge. Therefore, we have stated as part of future research that a deeper analysis of the underlying theoretical mechanisms must be performed.
Nevertheless, we believe that the results of our study are relevant. Although no significant differences in overall productivity were found, our results suggest that there are differences in terms of productivity on a deeper level of analysis. The implication of this finding is that in complex collaboration context as that studied in this research, a single holistic measure of productivity is too simplistic. Our results also provide a justification for deeper theoretical investigations and may direct future researchers to craft (field) experiments to study relevant theoretical mechanisms.

8. The construct of elaboration, presented on pp. 8-9, is a bit unclear. The authors note that an elaboration is a task relevant reference to a previous idea. They note that the response "I agree" would be counted as an elaboration. How does this elaborate the previous idea? Does the phrase "I do not agree" also count as an elaboration? I can see how "I agree" may be viewed as expanding on a previous idea, but "I do not agree" would seem to serve to stop consideration of a previous idea. What type of responses would not be seen as an elaboration? In one sense, given that an elaboration is a reference to a previously submitted idea, wouldn't this measure be related to the type of "one-track thinking" or reduced creativity observed in early studies of brainstorming groups?
This problem is not addressed in the response or the manuscript. Let me address it from a different angle. The authors make the argument that "serial teams will have higher elaboration measures" (Hypothesis H1a). However, in their conclusions, the message is that serial teams that elaborate more will produce a greater discussion of generated ideas. But, as I note above, the elaboration measure does not necessarily imply this. As I note above, an elaboration is defined as a task relevant reference to a previous idea. The example given, "I agree," would lead to deeper and more thorough discussion of the previous thought. However, the elaboration "I do not agree," which is also a task relevant reference to a previous idea would have the opposite effect: serving to lessen the "deeper and more thorough discussion" of the previous thought. My concerns are how was this type of elaboration coded, and how do the authors reconcile the fact that these type of elaborations lead to less, not more, thorough discussion of the previous idea? Moreover, this problem makes the primary take-home message from this study—that parallel groups generate more new ideas and serial groups generate more thorough discussion of generated ideas—questionable.
We think that there is a misunderstanding regarding the elaboration construct. In the paper an elaboration is defined as "a task relevant reference to a previously submitted unique idea". We have elaborated on the definition provided in the introduction to clarify this issue. We argue that contributions like "I agree" and "I disagree" both add meaning to a group's discussion. Both "I agree" and "I disagree" would therefore be coded and counted as an elaboration.

We did not define an elaboration in terms of how it could potentially spur further discussion. In fact, both an "I agree" or an "I disagree" contribution may either spur further reactions from people or give them a sense of 'completion'. We just argue that even simple

reactions should be counted as elaborations because they add meaning to the idea that they are in reaction to. An analysis of the effect of particular elaborations on the amount of ensuing discussion is beyond the scope of this study.

We have now included both the "I agree" and "I disagree" elaboration examples in the paper. We have also included a footnote to clarify that elaborations do not refer to encouragements for deeper discussion.

10. I had to re-read the procedure section several times to try to understand exactly how the brainstorming teams took part in this study, and I am still not sure. Here is what I believe: There were 10 teams in Organization 1. Five teams were assigned to Relay mode and five teams were assigned to Decathlon mode. The team sizes ranged from 4-11 members. The first Relay team did not differ from a Decathlon team—it simply started from scratch. Relay team 2 read the brainstorming results of Relay team 1, Relay team 3 read the results of Relay team 1 and 2, and so on. This seems problematic to me, because Relay team 5 is much more of a "relay" team than Relay team 2. The five Decathlon teams deliberated without reading previous results. It is not clear how long the sessions lasted. In Organization 2, there were six teams. Three teams were assigned to Relay mode and three teams were assigned to Decathlon mode. Again, the first Relay team did not differ from a Decathlon team—it simply started from scratch. So, by my estimation there was a total of 16 teams (although Table 1 indicates an n of 32). There were 8 Relay teams and 8 Decathlon teams; however given that the first Relay team in each organization did not differ from a Decathlon team, there were in fact 6 Relay teams and 10 Decathlon teams. Is this correct? I am not particularly confident that this is accurate, but that is what I surmise from pp. 13-15.
The description is a bit clearer. But my concerns were not addressed. To re-state: So, by my estimation there was a total of 16 teams (although Table 1 indicates an n of 32). There were 8 Relay teams and 8 Decathlon teams; however given that the first Relay team in each organization did not differ from a Decathlon team, there were in fact 6 Relay teams and 10 Decathlon teams. Is this correct? The point is that although there are 8 teams that are labeled serial teams and 8 teams that are labeled parallel teams, the first groups in the serial mode started at the beginning, just like parallel teams. So, functionally, there are 6 serial teams and 10 parallel teams. How is this accounted for?
We understand the reviewer's concern regarding this issue. We decided to count in the starting groups in the serial mode as serial groups as well as they were aware of the nature of their brainstorming mode, i.e. they knew that other groups would build on their results. This is stated in the paper. Therefore, it is possible that their approach and focus was different than that of the groups starting in parallel mode. To capture that we have included them in the analysis.

Further, if indeed the first serial group behaves more like a parallel group, it is likely that it will reduce the differences found, thus leading to a more conservative test. The first serial group did not get any information to react to and therefore it is possible that they had less elaboration than later groups. However, given the small number of groups that we have started with and the reasoning presented in the previous paragraph, we believe it is appropriate to include the first serial group as part of the serial group set.

The authors stated that they have corrected the overall N in Table 1, but this raises some further questions. First, why was the N originally deemed to be 32? Second, and more importantly, the data presented in Table 1 is quite different (means and correlations) from the data that was presented in the original manuscript. Why is this the case? This also

changed some of the data reported on p. 19. It would be informative if the authors specified why and how these changes were made.
These were unfortunate errors on our part. There was a conceptual mistake when the data was entered into SPSS which doubled the N. When the data was copied into the paper, the wrong table was copied. We apologize for this error. We double-checked the data and analysis this time to ensure that everything is correct.

Also on p. 19, I have reservations whether a "marginally significant difference" of p = .059 that is reported "supports the contention…" as the authors claim.
Given the small N, we initially felt this was an appropriate statement. However, we rephrased it to "offers some support for the contention…"

11. The implications drawn on pp. 21-24 far over-reach the data reported. For example, the authors state that "Based on our study, practitioners with very large brainstorming teams are encouraged to adopt a combined Decathlon-Relay approach." However, is there any data reported that examines a combined Decathlon-Relay approach? The remaining suggestions are similarly unsupported by the data presented.
The reviewer is correct that the recommendations go beyond the data. We decided to remove the combined serial-parallel approach discussion.

Running head: ASYNCHRONOUS ELECTRONIC BRAINSTORMING

Exploring Asynchronous Brainstorming in Large Groups: A Field Comparison of Serial and Parallel Subgroups

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Keywords: group problem solving, brainstorming, asynchronous collaboration, elaboration, productivity

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Abstract

Objective: To compare the results of two different modes of using multiple groups (instead of one large group) in order to identify problems and develop solutions. **Background:** Many of the complex problems facing organizations today require the use of very large groups or collaborations of groups from multiple organizations. There are many logistical problems associated with the use of such large groups including the ability to bring everyone together at the same time and location. **Methods:** A field study involving two different organizations, comparing productivity and satisfaction of group. The approaches included a) multiple small groups, each completing the entire process from start to end, and combining the results at the end (Parallel mode); and b) multiple subgroups, each building on the work provided by previous subgroups (Serial mode). **Results:** Groups using the serial mode produced more elaborations compared to parallel groups, whereas parallel groups produced more unique ideas compared to the serial groups. No significant differences were found related to satisfaction with process and outcomes between the two modes. **Conclusion**: Preferred mode depends on the type of task facing the group. Parallel groups are more suited for tasks where a variety of new ideas are needed, whereas serial groups are best suited when elaboration and in depth thinking on the solution are required. **Application**: Results of this research can guide the development of facilitated sessions of large groups or 'teams of teams'.

A Field Exploration of Asynchronous Brainstorming in Large Groups

Modern organizations frequently face problems of such complexity that no single individual has sufficient expertise, influence, or resources to solve the problem alone. Many organizations, therefore, depend on groups to execute projects and create organizational value. Collaboration has become an ever-present feature of organizational life. The ubiquitous nature of organizational collaboration has made group performance one the key challenges on any organization's agenda (Salas, Cooke, & Rosen, 2008).

Technological changes over the last decade have allowed organizations to use very large groups to solve problems or act on opportunities. Examples of such large collaborations include Communities of Practice in organizations that serve as forums for knowledge sharing, problem solving, and disseminating best practices (Bourhis, Dubé, & Jacob, 2005; Wenger, McDermott, & Snyder 2002), public participation in governmental policy making and evaluation (Bishop & Davis 2002; Macintosh 2004), or dynamic multi-agency collaborations during military missions (United States Joint Forces Command 2004). Such large groups allow organizations to bring their intellectual capital to bear in ways that were not previously possible. However, this kind of group work often progresses from a series of discrete events (e.g., a meeting or a workshop) to continuous collaboration (e.g., a 24/7 crisis response task force, military teams working on situational awareness, or online governmental town hall debates). In large scale collaborations, effective coordination of work among the group members can be challenging, especially when they have limited opportunities for direct communication to attune their tasks, for example when the group members

work in different shifts or do not have ways to reliably get a hold of each other whenever they need.

Organizations that use large groups to handle problems face a dilemma. The participative process must be completed quickly and at minimum cost. However, to benefit from available expertise and to achieve maximum buy-in for results, the participative process must involve as many stakeholders as possible. In other words, organizations must balance efficiency with completeness. One way address this dilemma is to employ collaboration technologies such as Group Support Systems (GSS) that have been found to effectively support large groups (more than 8 members) working on idea generation tasks (e.g., Dennis,1994; Dennis, Heminger, Nunamaker, & Vogel, 1990; Fjermestad & Hiltz, 1999). Using collaboration technology, group members may contribute simultaneously, may generate and evaluate ideas anonymously, and may contribute over extended periods of time working asynchronously (Agres, Vreede, & Briggs, 2005; Dennis, Wixom, & Vandenberg, 2001; Fjermestad & Hiltz, 1999).

Utilizing collaboration technology, however, does not address all problems facing very large groups (e.g., 20-100 people or even more). Organizing the work of a very large group presents logistical and technical challenges. For example, it may not be feasible to bring all group members to the same meeting place at the same time. In addition, having dozens of people generating ideas simultaneously can create information overload and overwhelm group members and leaders. Therefore, many organizations opt to split the larger group into subgroups that meet independently, working asynchronously with other subgroups. Multiple meeting times are offered and

group members typically sign up for the subgroup that fits their schedule best. The results of the subgroups are subsequently combined to produce the final outcome. This paper will explore the effectiveness of two options for organizing the work practices of such asynchronous subgroups: parallel mode and serial mode.

In parallel mode, each subgroup starts its brainstorming activity from scratch. In serial mode, each subgroup reads the ideas generated by earlier groups before beginning to brainstorm. For example, consider the case of a large group of upper level managers participating in a SWOT analysis at the beginning of a strategic planning cycle. Their schedules are too complex for all to participate simultaneously, so they divide into four subgroups, each with its own schedule and meeting. In *parallel* mode, each subgroup would begin from scratch, analyzing strengths, weaknesses, threats, and opportunities. In the end a facilitator integrates the work of the four subgroup and presents it to top management as the group's SWOT analysis. By contrast, in *serial* mode, the first subgroup might begin working on strengths analysis, and perhaps also contribute a start on weaknesses. The next subgroup would review their work, perhaps adding a few strengths, and then focus on weaknesses. If they have time they might start on opportunities. And so it would go for the other subgroups as well. The field studies reported in this paper explored serial and parallel groups that were involved in brainstorming problem statements and solutions.

The research question addressed is: How does the choice of work mode for asynchronous subgroups affect group productivity and group member satisfaction? While practitioners appear to use both approaches, to the best of our knowledge, no studies have empirically compared the utility of these two modes. The contribution of

our work is to empirically explore the effects of work mode choice as a form of inter-group coordination on phenomena relevant to successful collaboration. Specifically, the work presented here can inform us about how to coordinate work of large groups and work of multiple related groups ('teams of teams'). Finally, this study also answers the call by Salas and colleagues (2008) to increase our understanding of the dynamic assembly of groups (or 'teams of teams'). Furthermore, it represents a (field) study of groups 'in the wild', allowing a rich environment to provide for the context of the studies (Salas et al., 2008).

The remainder of this paper is structured as follows. The next section will provide basic background on group brainstorming. While no previous theoretical and empirical work has compared serial and parallel mode, we will extrapolate from current research on brainstorming to suggest hypotheses on the effect of mode on outcomes such as productivity and satisfaction. After presenting the design and results of the study, the paper concludes with a discussion of the key findings and their implications, the study's limitations, and directions for future research.

Background

Brainstorming in groups

Osborn (1957) developed brainstorming as a way to create synergy among people generating ideas in groups so that they could be more productive. However, subsequent studies showed that brainstorming groups could not outperform nominal groups (i.e. groups where the members work individually and then aggregate their results). It appeared that the losses from production blocking (i.e. the cognitive inability of a group member to simultaneously generate new ideas and listen to other

group members), social loafing (i.e. 'free riding' where people reduce effort when working in a group than when working individually), and evaluation apprehension (i.e. the fear of receiving negative criticism regarding contributions made to the group discussion) would outweigh any possible benefits from synergy in brainstorming groups (Collaros & Anderson, 1969; Diehl & Stroebe, 1987).

However, later research provided evidence that process structuring techniques, possibly embedded in collaboration technology, could alleviate these problems (Dennis et al., 2001; Niederman, Briggs, Vreede, & Kolfschoten, 2008). For example, it was found that if group members were allowed to generate ideas in parallel, they could outperform both traditional groups and nominal groups (Connolly, Jessup, & Valacich, 1990; Dennis et al., 1990; Fjermestad and Hiltz 1999; Gallupe et al. 1992). The simultaneous idea generation appeared to help groups to overcome production blocking and evaluation apprehension (Connolly, Routhiaux, & Schneider, 1993; Valacich, Jessup, Dennis, & Nunamaker, 1992). Studies using collaboration technology to allow for simultaneous idea generation suggested that electronic brainstorming groups generate more unique ideas and higher quality ideas than traditional brainstorming groups, and than either traditional nominal groups or electronic nominal groups (Dennis & Valacich, 1993; Dennis et al., 1990; Fjermestad & Hiltz, 1999; Gallupe et al., 1991; Gallupe et al., 1992; Nunamaker, Applegate, & Konsynski, 1987; Valacich, Dennis, & Connolly, 1994). In addition, studies have shown that groups using collaboration technologies can undertake ongoing brainstorming activities as part of longitudinal, continuous collaboration processes (Briggs, Adkins, Mittleman, Kruse, Miller, & Nunamaker, 1998).

Studies have also provided evidence that allowing group members to generate ideas anonymously could positively impact brainstorming productivity (e.g., Connolly et al., 1990). However, anonymity may be a mixed blessing. Social loafing literature shows that individuals tend to expend less effort in group tasks than they do in individual tasks, unless their contribution can be specifically identified, or unless they believe that their contribution is critical to the success of the task (e.g., Diehl & Stroebe, 1987; Harkins & Jackson, 1985; Kerr & Bruun, 1983; Paulus & Dzindolet, 1993; Sanna, 1992; Shaw, 1998). Thus, while anonymity may reduce evaluation apprehension and therefore stimulate individual group members to contribute, anonymity may also encourage social loafing as individual contributions cannot be identified. Research suggests that social comparison interventions can be used to mitigate social loafing (Shepherd, Briggs, Reinig, Yen, & Nunamaker, 1996). For example, a group leader can share performance indicators from peer groups with a group working on a brainstorming task which may stimulate them to achieve at least the same level of performance as their peers (Shepherd et al., 1996).

To summarize, group brainstorming can lead to synergy, which may raise the number and quality of ideas generated during brainstorming. Production blocking, evaluation apprehension, and social loafing may inhibit brainstorming productivity. Process structuring techniques, possibly embedded in collaboration technology, that allow for simultaneous contributions and anonymity, may overcome production blocking, and may reduce evaluation apprehension. However, anonymity may also increase social loafing, which reduces productivity. Social comparison interventions can mitigate social loafing during anonymous brainstorming.

Many studies on brainstorming use productivity as an indicator for success. Brainstorming productivity is traditionally defined in terms of the number of contributions that are generated during the execution of the group task (Litchfield, 2008; Reinig & Briggs, 2008). While determining and quantifying the number of ideas is fairly straightforward, it may not always be the best measure of productivity. For example, total counts do not take into account whether group ideas or discussions are on-topic or off-topic. Off-topic ideas do not have practical value, but may be included in the final count, inflating the total count value. Similarly, redundant comments can inflate the total productivity count.

Depending on the purpose of the brainstorming, other measures of productivity may be more appropriate than the number of ideas (Reinig & Briggs, 2008; Runco, 2008). Other approaches for evaluating productivity include subjective evaluations of quality of each idea or the originality of each idea (Dean, Hender, Rodgers, & Santanen 2006) as well as objective evaluations or the originality or uniqueness. The use of subjective quality and originality measures is common place in the study of creativity in individuals and groups (Reiter-Palmon, Herman, & Yammarino, 2008), but can be very time consuming, especially when there are a large number of individuals contributing many ideas. An objective measure of idea originality or uniqueness is a count of new ideas. Only ideas that are new and were not given before are counted as unique or original.

Borrowing from the creativity literature, another measure of productivity that can be used is that of elaboration (Kim, 2006). Elaboration refers to building upon, adding detail to an idea, or further contributing to an idea in a way that adds

meaning. Therefore any task relevant reference to a previously submitted idea may be considered an elaboration. In the context of a group, an elaboration is a task relevant reference to a previously submitted unique idea. A comment such as “Say, that could really work given our excess capacity!” to a previous unique idea, can be counted as an elaboration. As people elaborate on ideas, the ideas accrete meaning and significance among the group members. As meaning and significance increases, the usefulness of an idea as a thinking aid for the group increases, and so the value of an idea may rise. Even elaborations as simple as, "I agree" or “I disagree,” add meaning: not only does this idea exist, but it has a particular amount of support within the group. Elaborations may attach consequences and implications to the awareness of an idea[1]. Litchfiled (2008) indicated that no study has evaluated directly the combination and improvement of ideas or elaboration in brainstorming groups. As such, an evaluation of elaboration contributes uniquely to the literature on idea generation in groups.

As stated, no previous work has evaluated the differences between serial and parallel modes. As a result, our focus in this work is to determine whether the two modes differ in terms of different productivity measures. Previous work on brainstorming and idea generation suggests that simple and routine ideas are generated first as they are easier to think of (Buboltz, Schaeffer, Lofgreen, & Reiter-Palmon, 2004). More original and more complex ideas typically follow. In a serial

[1] Please note that we do not argue that certain types of elaborations may or may not stimulate additional discussion. Some groups members may feel encouraged to make further contributions after reading “I agree” or “I disagree”, while other group members may experience a sense of closure.

mode, later groups can benefit from the ideas developed by earlier groups. As a result, the later groups will not spend time repeating these early routine ideas, and will possibly spend more time either developing new ideas or elaborating on existing ideas. Further, this suggests that serial groups will generate fewer redundant ideas.

The exposure to previous work or previous ideas generated may have several additional consequences. First, serial groups will likely also have more ideas to react to, as they review ideas generated by previous groups. This may result in more elaborations. Second, as a result of viewing work performed by others, members in serial groups may feel pressure to perform (Michinov & Primois, 2005; Paulus & Dzindolet, 1993; Shepherd et al., 1996). Work on social comparison suggests that the knowledge of the performance levels of others can influence expectations and goals, leading to increased performance (Shepherd et al., 1996). Finally, exposure to previous work may serve to channel the groups that follow, by providing a focus on a specific direction, resulting in fewer new ideas being brought up[2].

In addition, it is possible that a serial group will elaborate more or focus on a number of ideas if they know that other groups will review their work and add to it, and that, by themselves, they do not need to complete the entire process. Serial groups thus may not feel rushed to move on and generate new ideas to a new issue. This would suggest that the focus of serial groups shifts somewhat from idea generation to elaboration. Based on the previous discussion the following hypotheses are suggested:

[2] We thank the reviewers for pointing out this possibility.

H1: There will be differences between groups using parallel mode compared to those using serial mode on various measures of productivity.

Participants in a parallel brainstorming session start with a blank slate, while people working in a serial brainstorming session read the ideas of others before working. In addition, those working in a serial mode are aware that this is the case and therefore are more likely to shift focus from idea generation to elaboration. As a result, they will have more ideas to respond to.

H1a: Serial groups will have higher elaboration measures than parallel groups.

Individuals working in serial groups will be able to see the work provided by others, which will likely include routine, simple and easy ideas, those that are more likely to be thought of by multiple people. Because these ideas are already listed, those working in a serial mode will not write them again. However, individuals working in a parallel groups will not know what other groups have done, and therefore will include those simple and routine ideas.

H1b: Serial groups will have fewer redundant ideas compared to parallel groups.

As indicated above, serial groups may provide more new ideas as routine ideas have already been developed and reviewed. However, the work of previous groups may channel the thinking of later groups resulting in fewer new ideas. As a result, no directional hypothesis is offered regarding the generation of new ideas.

Satisfaction in brainstorming groups

Many authors have reported satisfaction measures along with their brainstorming productivity results (e.g., Briggs, Dennis, Beck, & Nunamaker, 1993;

Connolly et al., 1990; Gallupe et al., 1992; Shaw, 1998; Valacich et al., 1994). A meta analysis by Fjermestad and Hiltz (1999) on technology supported collaboration shows that satisfaction was the second most frequently studied outcome after decision quality and was placed before productivity. This attention to satisfaction is not surprising as studies show that people who find their initial experiences with a technology supported work process dissatisfying tend be less motivated to be part of it in the future (for overviews, see Briggs, Reinig, & Vreede, 2008; Petter, Delone, & Mclean, 2008). Thus, regardless of the benefits of electronic brainstorming processes, group members will not be motivated to use them unless they are satisfied that these processes meet their needs (Agres et al., 2005).

We follow Briggs, Reinig, and Vreede (2006) who define a satisfaction response as 'an affective arousal with a positive or negative valence on the part of an individual toward some object' (Briggs et al., 2006, p.3). Meeting satisfaction is an instance of a satisfaction response with the meeting and its outcomes as objects-of-satisfaction. Meeting satisfaction can be further specified as two separate constructs: Satisfaction with meeting process (SP) is defined as 'an affective arousal on the part of a participant with respect to the procedures and tools used in a meeting' (Briggs et al., 2006, p.4). Satisfaction with meeting outcome (SO) is defined as 'an affective arousal on the part of a participant with respect to that which was created or achieved in a meeting' (Briggs et al., 2006, p.4).

In this study, we follow the model proposed by Reinig (2003) that frames SP and SO as a function of perceived net goal attainment (PNGA). Reinig (2003) defines PNGA as the extent to which a person feels that an object-of-satisfaction advances or

hinders the attainment of that person's salient individual goals. Reinig's model is based on Locke and Latham's goal setting theory (Locke, 1969; Locke & Latham, 1990) and assumes that a person holds various goals and that during a meeting some goals may be advanced (resulting in positive value appraisal) while others may be hindered (resulting in negative value appraisal). The model further assumes that one important goal that a person usually holds for a meeting process is to generate a satisfactory outcome. In other words, a meeting process that results in a satisfactory outcome is more likely to be satisfying than a process that results in a dissatisfactory outcome.

Reinig's model of meeting satisfaction suggests several circumstances under which either parallel or serial groups might be more satisfied. It is conceivable that some serial groups feel less satisfied, for example because they had to start first (and therefore will not have a chance to see what other groups think) or because they had to go last (and therefore will not have a chance to inspire other groups). It is also possible that parallel groups feel less satisfied if they realize that they may be re-doing the work already done by earlier groups. Parallel groups may also feel more satisfied knowing that they had the opportunity to out-do their peers.

Further, every parallel group has the opportunity independently to contribute the key ideas that eventually lead to a good outcome. All groups can then legitimately take ownership of and credit for the results. In the serial mode the first group in might contribute the key ideas, leaving subsequent serial groups to deal with only peripheral issues. Under this circumstance, the parallel participants might be more satisfied than serial groups. Yet, it is possible that the first serial group presents the most obvious ideas, allowing subsequent groups to delve deeper and become more

creative. The result could be a much more sophisticated and well-thought-out solution, leading the entire group to higher satisfaction that would not be available under the parallel mode.

The elaboration produced by the serial mode may deepen the meaning of contributed ideas and increase the value of those ideas for decision makers. People who make decisions based on unelaborated ideas may feel a sense of unease based on premature closure. They may feel that they did not fully "think the problem through" and therefore may be wary of the results. This may in turn reduce buy-in to the decision by reducing the sense that one's interests have been accommodated by the process and the results. This may in turn lead to reduced satisfaction. Therefore, we do not offer directional hypotheses and rather investigate whether differences in satisfaction exist based on mode.

Method

Organizations and Participants - The field study involved brainstorming of problem statements and potential solutions as part of projects in two different organizations. The first case concerned an Underground Logistics System (ULS), a project in the Netherlands that aimed to design and build a network of underground tubes between three hubs: a large international airport, a major flower auction, and a railway station. In the underground tubes, unmanned vehicles would transport goods between the three hubs. Given the high costs of this project and the large number of interested parties involved, a group of a 100 participants was invited from different organizations to discuss the diameter of the underground tubes. A choice had to be made between 3.5 and 5 meters, with the 1.5 meters difference representing almost

a doubling of the required project budget. In the course of this case, 10 subgroups participated in 10 brainstorming meetings.

The second case concerned a large student organization that had reconstructed a musical performance venue in their building. This so-called “Sound Box” had been constructed to assure that neighboring premises would not be bothered by the noise of rock band performances. The organization’s board wanted to consult their members (about 500) with respect to issues surrounding the successful management of this new facility, such as procedures and responsibilities for booking the facility and having independent verification whether sounds levels were within the allowable limits. In the course of this case, 60 members of the organization divided into six subgroups that participated in brainstorming meetings.

Procedure - In both cases a similar meeting process was employed. First, the members of a subgroup brainstormed about problems (in the ULS case about problems with respect to choosing a 3.5 meters tube, in the Sound Box case about problems with respect to the management of the previous facility). Second, the subgroups brainstormed about solutions for the problems identified in the first part of the meeting. Half the groups in each organization were randomly assigned to the parallel mode and half to the serial mode. Groups in the parallel mode started at the beginning to the brainstorming process, without any ideas. In the serial mode, the first group generated ideas, and each subsequent group started where the previous group left off. While the first group in the serial mode started at the beginning, similar to the parallel mode, group members were aware of the serial nature of the

work and that subsequent groups would complete what they had not finished. Groups ranged in size from 4-11 participants.

At the beginning of each session, the participants seated themselves behind a horse shoe shaped table, facing a projection screen at the front of the room. Each participant had his/her own GSS station. A facilitator welcomed the participants and introduced the session and its agenda. Next, a video was shown (in the ULS case) and a presentation was given by the session initiator. To conclude the introductory part of the session, the facilitator instructed the subjects about how to use the electronic brainstorming tool. During the introductory part of the session, the facilitator used a script to ensure that all groups received the same instructions. During the brainstorming tasks, the facilitator focused his activities on clarifying contributions and guiding discussion. The facilitator made no attempts to stimulate the participants to generate more ideas or direct them to certain parts of the problem or solution space. After the participants completed the brainstorming tasks, they filled out a meeting satisfaction questionnaire. Finally, the session initiator thanked the participants for their contribution to the project.

Dependent Variables – Several measures of group performance were collected focusing on group productivity and participant satisfaction.

Productivity - Productivity was evaluated by various measures of idea counts. Idea counts were produced by coding the electronic meeting logs (transcripts) of the brainstorming activities. All ideas were evaluated by trained raters. The inter-rater agreement ranged from 93% to 96%.

Raters evaluated and counted ideas in several ways. First, they determined the *total number of ideas* and the number of *unique ideas* generated by a group. A unique idea was defined as a verb-object combination that has not occurred previously in the transcript. For example, “Advertise the Sound Box”, “Advertise in the Newspapers”, and “Advertise on Television” would all be counted as unique ideas.

Second, the raters looked at the depth of the electronic discussion. More precisely, they determined to what extent ideas were *elaborated* upon. An elaboration is a task relevant reference to a previously submitted unique idea. For example, a comment “Yes, that will work if we monitored monthly usage.” to a previous unique idea, was counted as an elaboration. We measured elaboration in two ways. First, we measured the number of ideas that are elaborations. Second, we measured elaboration as a proportion of elaboration to maximum possible elaborations, or total number of ideas (however, excluding off topic ideas and redundant ideas). This was named the elaboration coefficient.

The elaboration coefficient, as a proportion, can range from 0.0 to 1.0. A score of 0.0 means that no ideas elaborated on previous ideas, each was a new thought. A score of 1.0 means that every idea after the first was an elaboration on the first.

Additionally, raters evaluated the number of redundant comments (those that were a repetition of previously made comment) and off-topic comments. Redundant comments were further divided into redundant new ideas and redundant elaborations. Counts for the problem generation and solution generation were combined to create one score on each measure for each session.

Participant Evaluation – The above measures provide objective and quantifiable measures of productivity. Subjective evaluations of group members were collected using a questionnaire. Specifically, two satisfaction constructs were measured using a modified version of the questionnaire developed by Briggs, Reinig, and Vreede (2006). Satisfaction with the meeting process (SP) included 6 items evaluated on a 5 point scale, and had a coefficient alpha of .76. Satisfaction with the meeting outcome (SO) included 5 items evaluated on a 5 point scale, and had a coefficient alpha of .79. A third construct, Perceived productivity, was measured using 5 items evaluated on a 5 point scale and had a coefficient alpha of .72.

Results

Table 1 presents the means and standard deviations for the group level variables, and their intercorrelations. Table 2 presents the means, standard deviations, and intercorrelations for participant evaluation data at the individual level.

To test Hypotheses 1, a MANCOVA was conducted using all measures of productivity as dependent variables, with mode (parallel vs. serial) as the independent variable and organization (ULS vs. Sound Box) as the covariate. As the MANCOVA indicated significant or marginally significant results, univariate ANCOVAs were conducted to identify the differences for each DV.

The results for number of unique ideas are presented in Table 3 and indicate a marginally significant difference between the mode groups (F = 4.28, p=.059, eta squared = .25). Groups in the parallel approach provided more unique ideas (M = 119.50, SD = 12.6) compared to the serial approach (M = 82.63, SD = 12.6). These

results offer some support for the contention that exposure to previous work may channel the thinking of subgroups working in serial mode.

The results for elaboration coefficient showed a significant difference between the two modes (F = 5.71, p<.05, eta squared = .31), with groups using the serial mode having a higher elaboration coefficient (M = .78, SD = .04) than groups using the parallel mode (M = .64, SD = .04), supporting hypothesis 1a. These results are presented in Table 4.

Finally, there was a significant difference between the two groups on the number of redundant ideas (F = 6.80, p<.01, eta squared = .34), with those in the parallel mode producing more redundant ideas (M = 37.38, SD = 4.1) than those in the serial mode (M = 22.25, SD = 4.1). These results support hypothesis 1b. Results are presented in Table 5.

No significant differences were found for off-task comments, number of elaborations, redundant elaborations, or total number of ideas.

Tests for the satisfaction outcomes were conducted using individual level data. Perceived productivity, process satisfaction, or satisfaction with meeting outcome were the dependent variables, mode (parallel vs. serial) as the independent variable, and organization was a covariate. No significant differences were found for these evaluation variables based on mode.

In addition to the quantitative data from the questionnaires, we also collected some qualitative feedback in the form of written comments that the participants made voluntarily to some of the Likert questions and to some open-ended questions. Looking for common themes, we found that participants using parallel mode felt that

the electronic discussions did not always display enough nuance to the issue at hand. According to one participant "*It [the results] could use some more detail.*" Interestingly, participants using the parallel mode sometimes felt the amount of elaboration itself was insufficient: "*There is less discussion because of this [electronic] way of brainstorming; moreover, there are fewer exchanges of ideas and people elaborate less on each other's ideas. It should be combined with more oral discussions.*" Using serial mode, on the contrary, there were no negative comments about discussion nuance and amount of elaborations. The participants using the serial mode did, however, complain about the effort needed to familiarize themselves with the results from preceding groups. This is illustrated by such comments as "*We needed more time.*", "*It [the session] was a bit too short to get a good overview.*", and "*There was a lot that had to be read and hence we lost a lot of time.*"

Discussion

The results indicate that there was no significant difference in overall brainstorming productivity between parallel and serial groups in terms of total ideas (including unique ideas and elaborations). However, parallel groups produced more unique ideas (although this result was marginally significant), whereas groups using the serial mode produced significantly more elaborations. Hence, we may conclude that neither method is superior in terms of productivity. Rather, each mode seems to be more effective for different operationalizations of productivity. The preference for either method depends on the purpose of the group work: If the purpose is to identify as many new ideas as possible, the parallel approach appears to be more suitable. If the purpose is to encourage a thorough discussion of generated ideas and elaboration,

then the serial approach appears to be more suitable. More importantly, the different modes were not related to satisfaction or perceived productivity, indicating using a particular mode will likely not result in decrease in satisfaction and use of the process.

One advantage of the serial approach over the parallel approach is that the facilitator does not have to merge the transcripts after the sessions and consolidate overlapping and identical ideas. For example, in the ULS project, the facilitator needed about three working days to consolidate the results of the groups that worked in parallel into a single document.

Because the study was carried out in the field, we did not have control over group size. The Sound Box group sizes were comparable: the average sizes were 9 and 10 for parallel and serial mode respectively. However, in the ULS case, the average parallel mode group size was 8, compared to 5.5 for the serial groups. The literature suggests that group size may have a significant impact on productivity in computer supported brainstorming groups, where larger groups appear to be more productive than smaller groups (Dennis & Valacich, 1993; Gallupe et al., 1992; Valacich et al., 1994). Bearing this in mind, it can be argued that in the ULS case the serial groups were actually disadvantaged compared to the parallel groups. Still, in the ULS case the serial groups outperformed the parallel groups in terms of elaborations, while there was no significant difference in overall number of ideas.

Finally, from the qualitative feedback from the participants, it also appears that participants in the serial and parallel groups were satisfied and dissatisfied with

different aspects of the process. These differences were not covered by the global measures for satisfaction that we used.

Implications

Based on the results of this study, a number of implications for research and practice can be presented.

From a research perspective, this paper is the first that we are aware of that empirically compares the effect of utilizing different approaches to managing a large group by using multiple subgroups for brainstorming. Specifically, we compared the effects of serial and parallel modes of using multiple subgroups for brainstorming and compared the effects of mode on various measures of productivity and satisfaction. The results provide a starting point for researchers interested in coordination of multiple teams and the use of technology in brainstorming groups. This study provides us with initial evidence of possible strengths and weaknesses of the parallel and serial approaches. Additional work needs to further support these findings and evaluate the mechanism by which these approaches differ empirically.

In addition, we evaluated multiple measures of productivity, not just a total idea counts. This approach provided unique insights into the use of these different modes for coordinating the work of multiple groups, as each mode was effective for different measures of productivity.

The results here underscore the importance of utilizing different measures of productivity in group brainstorming research. As indicated previously, different conclusions regarding the effectiveness of the two modes can be reached, depending on which productivity measure is being evaluated. These results mirror similar results

obtained in other areas which suggest that various outcomes, while related, are affected differently by different tasks, instructions, and processes (Reiter-Palmon, Illies, Kobe, Buboltz, & Nimps, 2009).

Practitioners in the field have dealt with the coordination issues associated with very large groups or multiple smaller subgroups ('teams of teams'). However, research in this area is lagging. Both the use of very large groups and the use of smaller subgroups present coordination difficulties. As collaboration technologies such as GSS make partitioned work in very large groups possible, understanding the issues surrounding the integration of work by asynchronous subgroups is important. This paper provides an initial understanding of the issues associated with the coordination of multiple subgroups, as well as an initial understanding of how these issues may be addressed.

From a practical perspective, this study has implications regarding the coordination of work of multiple groups. If multiple groups are used for asynchronous brainstorming leaders need to make a conscious decision whether to strive for a larger number of unique ideas or a deeper discussion of generated ideas. In situations where discussion is considered most important, for example in preference tasks where the goal is to find consensus among the participants, our findings suggest that group leaders should consider designing the meeting agenda and procedures following the serial approach so that more discussion is stimulated.

Limitations

There are several limitations of this study that have to be taken into account when interpreting the results. First, because the study was carried out in the field we

could not exercise the same level of control over events as is common in a laboratory environment. We had, for example, no influence over the number of participants per subgroup or the exact composition of each subgroup. Second, our study included just two case situations. While we were able to control statistically for organizational effects by covarying this variable, it is unclear to what extent the specific characteristics of the case situation (e.g. organizational environment, task) had an effect on the results. Third, we did not measure idea quality in this study. We did not have objective measures to determine the quality of individual ideas and the tasks did not have a "correct" answer. Although we observed that almost all contributions were faithful and serious, it remains to be seen whether the brainstorming mode had an effect on idea quality. Notwithstanding these limitations, we feel that the advantages of studying real groups in a natural environment outweigh these limitations. Finally, the measures of satisfaction were highly correlated in this study and showed no differences between the two modes. The satisfaction scales used were developed and validated and these three constructs were found to be distinct in past work (Briggs et al., 2006), indicating that this result might not be specific to the current samples.

Conclusions

Modern organizations and communities often employ large groups to work on complex problem solving and decision making tasks. Due to the complexity of managing large groups, these groups are often split up into smaller subgroups to work on the same task asynchronously. These smaller groups can either work in parallel mode (where each subgroup starts working on the task with a clean slate) or in serial mode (where each subgroup builds on the results from a previous subgroup). This field

study compared parallel and serial subgroups working on brainstorming tasks. The results indicate that asynchronous subgroups following a serial approach outperform parallel subgroups in terms of idea elaborations. Parallel subgroups outperform serial subgroups in terms of unique ideas generated. No significant differences were found between modes in terms of overall number of ideas generated, perceived productivity, satisfaction with process, and satisfaction with outcomes.

This exploratory field study presented a first investigation of productivity effects in subgroups working under different brainstorming approaches. Future research should focus on measuring relevant underlying theoretical mechanisms that may provide a deeper understanding of the reported findings, such as synergy, social loafing, social comparison, and evaluation apprehension. From a methodological perspective, we wish to collect more field data, so that we have a broader quantitative basis for the statistical analyses. Also, it would be advisable to design a controlled laboratory experiment to confirm the results of this study. For such an experiment special attention is required for an appropriate task, a task that is complex enough for a number of serial and parallel subgroups to work on. From a practical perspective, a key question remaining concerns the optimal number of serial subgroups. During the study, we did not notice any saturation effects during the course of the serial treatments. Yet, the question is at what point the $(n+1)^{th}$ group no longer adds productive and meaningful contributions to the results of the previous n groups?

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Table 1

Means, standard deviations and correlations for productivity measures (n=16)

Variable name	Mean	SD	E	EC	OT	RI	RE	TI
Unique Ideas (UI)	101.06	68.77	.67**	-.01	.78**	.82**	.59*	.85**
Elaborations (E)	190.25	138.33	-	.62*	.76**	.78**	.90**	.96**
Elaboration Coefficient (EC)	0.71	0.13		-	.24	.29	.60*	.44
Off-Task (OT)	7.69	11.59			-	.58*	.77**	.83**
Redundant Ideas (RI)	29.81	22.52				-	.74**	.86**
Redundant Elaborations (RE)	18.81	15.55					-	.86**
Total Ideas (TI)	291.31	191.42						-

**p<.01, *p<.05

Table 2

Means, standard deviations and correlations for individual evaluation measures (n=96)

Variable Name	Mean	SD	SO	PP
Satisfaction with Process (SP)	24.84	3.36	.74**	.65**
Satisfaction with Outcome (SO)	19.26	3.02	-	.70**
Perceived Productivity (PP)	16.54	2.30		-

**p<.01

Table 3

ANCOVA for number of unique ideas with organization as a covariate

Source	Type III Sum of Squares	df	F	Sig.	Partial Eta Squared
Corrected Model	54430.900(a)	2	21.424	.000	.767
Intercept	107288.139	1	84.458	.000	.867
org	48991.838	1	38.567	.000	.748
type	5439.063	1	4.282	.059	.248
Error	16514.038	13			
Total	234363.000	16			
Corrected Total	70944.937	15			

a R Squared = .767 (Adjusted R Squared = .731)

Table 4

ANCOVA for elaboration coefficient with organization as a covariate

Source	Type III Sum of Squares	df	F	Sig.	Partial Eta Squared
Corrected Model	.102(a)	2	4.039	.043	.383
Intercept	.958	1	75.674	.000	.853
org	.030	1	2.373	.147	.154
type	.072	1	5.705	.033	.305
Error	.165	13			
Total	8.368	16			
Corrected Total	.267	15			

a R Squared = .383 (Adjusted R Squared = .288)

Table 5

ANCOVA for number of redundant ideas with organization as a covariate

Source	Type III Sum of Squares	df	F	Sig.	Partial Eta Squared
Corrected Model	5856.400(a)	2	21.752	.000	.770
Intercept	10285.357	1	76.404	.000	.855
org	4941.338	1	36.706	.000	.738
type	915.063	1	6.797	.022	.343
Error	1750.038	13			
Total	21827.000	16			
Corrected Total	7606.438	15			

a R Squared = .770 (Adjusted R Squared = .735)

Biographies

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