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ABSTRACT: Collaborative brainstorming is often followed by a convergence activity where teams extract the most promising ideas on a useful level of detail from the brainstorming results. Contrary to the wealth of research on electronic brainstorming, there is a dearth of research on convergence. We used experimental methods for an in-depth exploration of two facilitation-based interventions in a convergence activity: attention guidance (focusing participants on procedures to execute a convergence task) and discussion encouragement (engaging participants in conversations to combine knowledge on ideas). Our findings show that both attention guidance and discussion encouragement are correlated with higher convergence quality. We argue that attention guidance's contribution is in its support of coordination, information processing, and goal specification. Similar, we argue that discussion encouragement's contribution is in its stimulation of idea clarification and idea combination. Contrary to past research, our findings further show that satisfaction was higher after convergence than after brainstorming.

KEY WORDS AND PHRASES: attention guidance, brainstorming, collaboration, collaborative brainstorming, discussion encouragement, idea convergence, idea quality, idea selection, ideation, satisfaction, team, teamwork.

Increased market competition, fast technological developments, and the dynamic environment in which organizations function set increasingly challenging requirements on an organization's ability to solve problems and make decisions. To address such challenges, organizations rely on the collaborative development of ideas, in both small teams and large crowds [39, 45]. Since the 1950s, a vast body of literature has developed on brainstorming or ideation, spanning different disciplines such as psychology, information systems, and management [30, 67, 76]. This research shows that under a variety of conditions, teams using collaboration technologies and techniques may produce more ideas of higher quality than individuals who do not use such support [30, 31, 37, 76].

However, brainstorming by itself is insufficient for organizational value creation. It is an early step in a collaborative idea development process but does not produce a single final solution or decision [42, 45]. In fact, most brainstorming techniques and technologies aim to generate high volumes of ideas to increase the likelihood that some promising ideas will be part of the results [15]. There are many examples of high brainstorming productivity: a team of end-user representatives working with information systems (IS) professionals can generate hundreds of user stories in a matter of hours [26]. A team of military decision makers can identify dozens of possible courses of action in response to an external event or threat [12]. Emergency response workers can easily collect hundreds of ideas to bring relief to areas that have been struck by natural disaster [84]. Brainstorming productivity gets even more pronounced in settings that use social media and online collaboration technologies. Employees using enterprise social networking applications can effortlessly share vast quantities of ideas, insights, and feedback [58]. Online crowds can generate thousands of ideas in a matter of hours [11]: IBM's Innovation Jam gathered 45,000 ideas [9], and 1,200 ideas were submitted to Cisco's I-Prize competition [51]. However, brainstorming productivity gives rise to a new challenge: many idea generation techniques and technologies enable teams to generate many more ideas than they can meaningfully attend to for evaluation and selection within a reasonable amount of time. With increased idea numbers comes an increased need for information processing, resulting in information overload [42].

In the 1970s, Herbert Simon famously predicted that, in the future, the scarcest resource would be human attention [87]. That future is upon us. When teams face a large number of ideas, they do not have the cognitive attention and processing resources to consider the meaning and qualities of each idea in turn to identify the best one; they get overwhelmed with the amount of information they need to process [35, 48]. Teams thus need to transition from a situation where they have generated a vast number of ideas to having a limited quantity of promising ideas that can be carefully considered and compared on their individual merits [45, 59]. This transition is called *convergence*—reducing the number of ideas in a shared set to a few that the team deems worthy of detailed attention while clarifying those ideas to increase shared understanding [13]. A successful convergence activity allows a team to expend their limited time and cognitive resources on a thorough processing of selected ideas that they consider the most promising. Without a successful convergence activity, a team may be faced with too many ideas to consider or different interpretations of the generated ideas among the team members. Furthermore, they may end up with many solutions that are underdeveloped—for example, because no consolidation of idea fragments has taken place.

Thus, productive online idea generation necessitates convergence. Yet, this is easier said than done. Convergence can be time consuming and difficult. It becomes more challenging as brainstorming productivity and time pressure to make a decision increase (e.g., [42, 75]). Moreover, in the mid-1990s, researchers discovered that team satisfaction levels tended to drop during subsequent activities as the cognitive load for identifying redundancies, clarifying meanings, and considering relevance increased [20]. Also, team leaders reported that convergence is the most challenging team activity to facilitate [29].

Compared to the brainstorming literature, relatively few studies have been done on convergence. Some researchers have focused on different forms of technology support for idea selection and evaluation activities (e.g., [60]). Other researchers have studied interventions, such as feedback, facilitation, and teamwork guidance on processes that involved convergence activities (e.g., [8, 93]). Yet these studies do not investigate convergence as a distinct activity separate from other collaboration activities such as idea generation, idea evaluation, or idea selection. Studying a collaboration process as a whole makes it difficult to understand what influences convergence activities and outcomes. Consequently, little is known about the effects of different interventions on the outcomes of convergence activities and on the attitudes of team members toward these interventions and outcomes.

To address these research gaps and gain a deeper understanding of team convergence activities, we investigate the effects of different interventions in a convergence activity on team member perceptions and convergence outcome quality. Specifically, we investigate how variations in the way in which team members' attention is guided and team members are encouraged to discuss ideas correlate with different levels of convergence outcome quality. Our study also examines differences in satisfaction with process and product between the idea generation and convergence activities in a collaborative idea development process. Thus, the overall research questions that this study seeks to answer are the following:

- How do different types of structuring interventions relate to convergence outcome quality?
- How does participant satisfaction evolve from the generation to the convergence activity during a facilitated idea development process?

To the best of our knowledge, our study is one of the first in-depth investigations of convergence activities in teams. Given the paucity of previous research, we performed an exploratory study using experimental methods in the laboratory where participants generated and converged ideas in the context of a crisis response task. Our findings suggest that, under the conditions of this study, providing attention guidance and discussion encouragement are both associated with higher outcome quality. The findings further show that, contrary to past research, facilitated convergence techniques may actually be associated with higher levels of satisfaction than those observed after idea generation. We expect the results of our study to inform the design of procedures for conducting convergence activities as well as the design of new online technologies to support such procedures. This may benefit organizations to better manage and process large idea sets originating from technology-supported ideation efforts.

Background

Convergence

Convergence has been identified as one of five patterns of collaboration that characterize how teams execute activities that are part of a collaboration process: generation, convergence, organization, evaluation, and building commitment [13]. A formal definition of convergence is "to move from a state of having many concepts to a state of having a focus on and understanding of the few worthy of further attention" [13, p. 47]. During a convergence activity, a team extracts and refines the most promising ideas from a larger idea set such that they increase shared understanding and can proceed to evaluate a manageable number of ideas in more detail [13, 22]. In other words, a convergence activity starts with a collection of ideas, which need to be reduced and clarified to prepare for further detailed consideration. Consequently, some researchers differentiate between two subpatterns that are interdependent and often, but not always, occur simultaneously during convergence activities: reduce and clarify. Reduce means “to move from having many ideas in the shared set to a focus on the few deemed worthy of more attention” and clarify means “to move from less to more shared understanding of ideas in the shared set” [25, p. 127].

There is no single measure to determine the success of a convergence activity. For example, a convergence activity can be considered successful if it reduces a larger idea set to a very small one that is easy for the team to process in detail. Yet, the same activity would not be considered successful if high-quality ideas did not make it into the small idea set. Similarly, a convergence activity may result in the optimal subset of ideas with only the most effective solutions to a problem at hand, yet the team members may be very dissatisfied with the way in which the convergence activity was executed, therefore undermining their acceptance of the outcomes. Researchers have thus proposed different measures for convergence quality. Some measures focus on the convergence process itself, such as the time needed to complete the convergence or participants’ satisfaction with the process [8, 22]. Other measures concern the outcome of convergence, such as the quality of the resulting idea set, satisfaction with the product, and shared understanding concerning the idea set [8, 22, 27]. Idea quality is a multidimensional concept, which can be measured by idea originality or uniqueness, relevance to the task at hand, and elaborateness in terms of being developed to a useful level of detail [8, 22, 25, 27, 42]. An idea can be considered unique if it is semantically nonredundant compared to the other ideas in an idea set [27]. Task-relevant ideas can be understood as ideas that aim to meet the goal of the task and fulfill the basic requirement to be considered an idea—that is, “an actionable object–verb phrase that is presented as a potential solution to the task at hand” [15, p. 3]. Level of detail relates to idea specificity—the extent to which an idea is developed and has a complete and elaborate description [27]. An idea’s level of detail is therefore useful to the extent that it is sufficiently elaborated to be evaluated in the final phase of the idea development process. This is typically evidenced by the idea’s depth of development [34] or extent of description [19].

Structuring Interventions for Convergence

To increase the likelihood of high idea quality in the result set, convergence, as well as any other collaborative activity, can be supported with structuring interventions. Structuring interventions are bundles of instructions, based on human or information technology (IT), for team members to engage in productive actions and to restrict unproductive actions during the execution of a collaborative activity [18]. Such interventions have also been referred to as facilitation [4, 93], feedback [49, 50, 52], or coaching [91]. Structuring interventions can be directed at the process [89], the task [30], or how to use supporting technology [41]. With interventions into the process, a human or automated facilitator provides procedural support for helping teams to coordinate and manage collaboration activities [89]. With interventions into the task, a human or automated facilitator offers insights, interpretations, and sometimes also opinions about the problem and/or proposed solutions [10, 30]. With interventions into the handling of technology, a human or automated facilitator helps team members to use the functions of a collaboration technology and to capture team outcomes [32].

A review of empirical studies on structuring interventions in collaboration processes that include convergence activities, leads to two observations. First, most past studies have focused on structuring interventions that were targeted at the collaboration process as a whole, not solely on the convergence activity. For example, past research has examined convergence (1) in connection with generation and evaluation [38, 89, 93, 94], (2) in larger collaboration settings considering additional activities such as problem analysis, organization, and building commitment [4, 32, 54, 66], or (3) did not specify distinct collaboration activities [50, 52, 59, 61, 80, 91]. When applied to multiple activities or to the collaboration process as a whole, the structuring intervention is not conceptually connected to a specific activity outcome. Yet structuring interventions are typically not static across activities but will change with the collaboration activity as they aim for different outcomes. For example, a facilitation intervention for idea generation may stimulate participants to come up with a large number of creative ideas (thus, outcome focus = productivity) and a facilitation intervention for building commitment seeks agreement (thus, outcome focus = consensus), while a facilitation intervention for convergence strives to foster shared understanding of selected ideas among participants [25]. These examples show that it is difficult to isolate the effects of a structuring intervention on convergence outcomes if it is applied to the whole idea development process.

Second, the effects of studied interventions on various relevant convergence measures appear to be inconclusive. For example, the effects of facilitation interventions on idea quality and satisfaction are mixed. While some studies found positive effects on idea quality [94] or satisfaction [59, 61, 66, 69, 89, 94], other studies revealed that structuring interventions might have no effect or even have negative effects on idea quality [38, 69, 92] or satisfaction [89, 91]. Past research reported similarly mixed findings regarding outcomes such as performance [4, 32, 50, 61, 80, 91], decision quality [38, 59, 66, 89, 93], learning [52], and consensus [32, 38, 69, 89, 92].

Again, mixed findings might be the result of investigating effects of multiple structuring interventions at the end of the collaboration activity and not considering interim outcomes that focus on the convergence activity in isolation. Such focused studies are important as earlier activities may influence the outcomes of later activities. For example, consider facilitating an idea development process with distinct structuring interventions for generation, convergence, and evaluation. The collaboration success could be assessed at the end but one would not know how each of the structuring interventions performed. The generation intervention could have been effective, providing a good starting point for convergence, but the convergence intervention could have been ineffective, delivering low-quality input to the evaluation activity. Even if the structuring intervention for evaluation were of high quality, we would suffer overall performance loss. Hence, studying relevant collaboration outcomes (such as idea quality or satisfaction) after each activity is important to understand the effects of a structuring intervention aimed to support that activity. Thus, research needs to look beyond holistic interventions in a complete collaboration process and focus on interventions that specifically target convergence outcomes.

Based on the above, we argue that our understanding of facilitated convergence can benefit from a perspective that focuses on the purpose of a structuring intervention as it relates to the intended outcomes of convergence. Therefore, we conceptualize a structuring intervention to consist of one or more facilitation components each of which represents a set of related instructions intended to affect a particular convergence outcome. We use this conceptualization to explore the relationship of two facilitation components, attention guidance and discussion encouragement, with convergence quality. In the next section we develop exploratory conjectures to study how our implementation of attention guidance and discussion encouragement relates to convergence quality. We also describe exploratory conjectures regarding the evolution of participants' satisfaction from facilitated idea generation to convergence.

Development of Exploratory Conjectures

Attention Guidance

Our review of related work shows that many studies investigated structuring interventions as a series of instructions to make a collaboration process more effective [2, 4, 32, 38, 59, 66, 69, 89, 91, 92, 93, 94]. Such structuring interventions were reported to increase uniqueness of ideas [94], usefulness of ideas [2], decision quality [59, 66, 93], satisfaction [66], performance [4], and decision confidence [89].

A key reason for the observed positive effects may be the way that structuring interventions shift an individual's attention [66] either to the task or the process. Attention is the allocation of cognitive processing resources to a selection of available information while ignoring other observable information [3]. A facilitator who is cognizant of the team's goal may draw the team members' attention to the task by pointing out potential misfits among explicated ideas [47]. Guiding attention (re)focuses team members on the goals of their activity and limits nontask behavior [1] so that team members' individual cognitive resources can be used to work on the task at hand. Researchers found that such a guidance of attention influences information processing in teams [41] to avoid shallow processing of exchanged information [83], support selecting relevant or dropping irrelevant information [2, 66] and keep interactions on topic [21, 93]. Furthermore, human or IT-based facilitation may guide the attention toward the process by directing team members through a sequence of process steps [2, 59, 92]. Such structuring interventions reduce the need for the team members to coordinate their activities [1]. Teams that spend more resources on their actual task are more likely to produce high-quality deliverables [85].

Therefore, we conceptualize *attention guidance* as a facilitation component that comprises a set of instructions to focus participants on the task at hand during the execution of a convergence activity. As attention guidance provides instructions about when and how to reduce or clarify, team members do not need to come up with and agree on their own procedures. This should give facilitated teams more time to pay attention to the ideas and process the meaning of idea descriptions in more detail. As attention guidance enables teams to more effectively allocate cognitive resources to the reduction and clarification of ideas, we argue that attention guidance may be positively associated with convergence quality. Thus:

> *Exploratory Conjecture C1:* Teams receiving attention guidance as implemented in this study will produce idea sets of higher convergence quality than teams receiving no attention guidance.

Discussion Encouragement

Our review of the literature also shows that the operationalization of facilitation is often characterized by instructions that explicitly stimulate conversations [69, 89, 92] or encourage discussions of different viewpoints within the team [59]. In connection with other structuring interventions, researchers found the encouragement of discussions related to increased decision quality [59], performance [4], and decision confidence [89].

It has been argued that during team discussions team members collectively engage in collaborative learning processes [6, 90] because they become aware of their own and others' perceptions [65]. This leads to the externalization of individual mental models [70, 73], which allows teams to further develop ideas by rearranging, reorganizing, and redefining existing knowledge [53]. To this end, discussion encouragement offers opportunities to collectively develop ideas employing team members' abilities and motives to exchange knowledge [5, 8, 68]. Discussions allow team members to build shared understanding of ideas and their properties by identifying overlaps or elaborating on differences in their individual mental models to increase the degree to which they concur on the interpretation of the idea set [8, 23, 68]. Such interactive groups should then also be able to converge on their understanding and synthesize generated ideas into more novel combinations [54].

Therefore, we conceptualize *discussion encouragement* as a facilitation component that consists of a set of instructions to actively engage teams in conversations to clarify and reduce ideas during a convergence activity. Discussion encouragement may comprise a procedure that assists individual team members to contribute to conversations and creates opportunities to interact in groups. The instructions may stress the importance of these interactions by stating that the work product of convergence should capture the outcome of the conversations. We argue that *discussion encouragement* may be positively associated with convergence quality. This leads to our second exploratory conjecture:

> *Exploratory Conjecture C2:* Teams receiving discussion encouragement as implemented in this study will produce idea sets of higher convergence quality than teams receiving no discussion encouragement.

Satisfaction

Satisfaction is an affective perception on the part of an individual toward some object [14, 16]. Team member satisfaction is a critical condition for the sustainability of facilitation techniques to support convergence [40]. Even though a facilitation technique or technology may result in outcomes of demonstrably superior quality, if a team feels dissatisfied with the process support they are exposed to, they are less likely to participate in future such efforts (e.g., [7, 14, 81, 82]). Thus, it can be argued that team members need to experience a feeling of satisfaction with the results and proceedings of a convergence activity for a convergence intervention to be considered successful [28, 77].

Briggs et al. [16] proposed a yield shift theory (YST) of satisfaction, which posits that satisfaction manifests in response to shifts in yield for an individuals' set of active goals. YST assumes that individuals hold multiple goals and cognitively ascribe some level of utility to each active goal—a sense of how much benefit would manifest were the goal obtained. Another cognitive mechanism assesses the likelihood that an active goal will be attained, and a third synthesizes a yield for a goal that is proportional to its utility, but reduced in inverse proportion to its likelihood. Thus, a high-utility, low-likelihood goal may have a similar yield to a low-utility, high-likelihood goal. YST assumes that when the overall yield for an individual goal set changes (shifts), then it triggers a satisfaction response proportional to and in the direction of the shift.

If the team members' goal is to develop a set of high-quality ideas that may solve a complex problem, then, if the logic of YST holds, they must experience higher levels of satisfaction after a convergence activity than after the preceding brainstorming activity: The convergence activity supports the team to produce a list of high-quality ideas from a larger collection of raw brainstorming results. So, they might feel they have gained more utility from the convergence than from the brainstorming (a positive utility shift, producing a positive yield shift) and thus at that point feel more satisfied about the collaboration process. Having a collection of focused, high-quality ideas in hand to address their problem might also increase their belief in goal attainment after convergence in comparison to after brainstorming (a positive likelihood shift, producing a positive yield shift). So, they might experience a more positive satisfaction response regarding their outcomes after the convergence process than after the brainstorming process. Therefore, facilitated teams (i.e., teams that receive attention guidance or discussion encouragement instructions as implemented in our study) may experience higher levels of satisfaction after convergence than after brainstorming:

> *Exploratory Conjecture C3:* Facilitated teams will report higher levels of process satisfaction after convergence than after brainstorming.

> *Exploratory Conjecture C4:* Facilitated teams will report higher levels of product satisfaction after convergence than after brainstorming.

Method

Design of Treatments

We used experimental methods in a laboratory setting to explore the associations between attention guidance (AG) and discussion encouragement (DE) with convergence quality in a fully crossed 2 × 2 factorial design (Figure 1). One treatment provided attention guidance (AG+/DE– teams). Another treatment provided discussion encouragement (AG–/DE+ teams). The third treatment provided both attention guidance and discussion encouragement (AG+/DE+ teams). The fourth treatment was unfacilitated; we provided neither attention guidance nor discussion encouragement (AG–/DE– teams). In the fourth treatment, we had no control over the mode a team would be working in as teams that do not have the benefit of a facilitated process may go back and forth between generation and convergence activities. Consequently, we conceptualize the AG–/DE– treatment groups as performing a single idea development phase as there were no clearly separated generation and convergence phases.

With attention guidance, facilitators may decompose the convergence activity into steps and guide the team members to execute each step. In our implementation of attention guidance, we decomposed the convergence task into reduction and clarification, specified goals for the convergence task and split the list of generated ideas

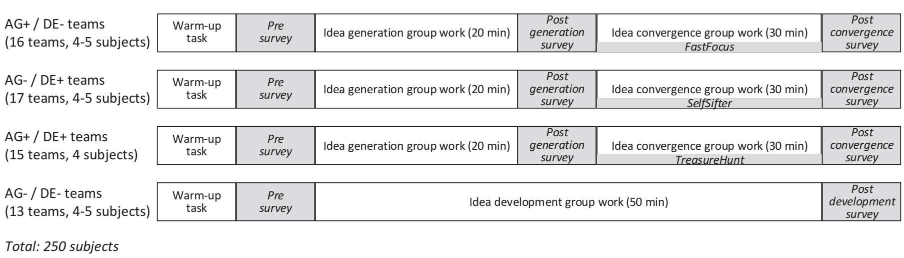

Figure 1. Treatments, Participants, and Procedure

into separate lists each containing a subset of ideas. For example, we used specific prompts to let subjects pick one idea out of their assigned idea list, for example, “Please select a help measure in the next 30 seconds,” or asking them to clarify the idea, for example, “Could you specify in a bit more detail?”.

With discussion encouragement, facilitators may initiate conversations among team members to clarify the meaning of ideas in discussion groups. In our implementation of DE, we stimulated individuals to engage in conversations to clarify ideas and to combine their knowledge to discuss ideas that were not necessarily their own. For example, we used prompts to initiate communication, for example, “Please have a conversation to reduce and clarify the list of ideas,” and to invite participants to share their knowledge, for example, “You now have the opportunity to discuss the ideas.” Appendix A provides a detailed description of the treatments implemented in our study.

Participants, Facilitators, and Task

We randomly assigned 250 participants from an undergraduate information systems course to 61 teams (55 four-person teams and 6 five-person teams). We had 65 students collaborate in 16 AG+/DE– teams, 70 students in 17 AG–/DE+ teams, 60 students in 15 AG+/DE+ teams, and 55 students in 13 AG–/DE– teams (Figure 1). Student teams worked in office rooms having five work places equipped with personal computers and 24-inch monitors, which we positioned such that participants could talk to each other face-to-face. Students received course credit for their participation.

Six teaching assistants, four Ph.D. candidates, and one postdoc researcher acted as facilitators. They were trained in what to monitor and what instructions to give in each treatment group. This training included a videotaped demonstration of each structuring intervention for convergence with a team of volunteers by a professional facilitator. We performed test sessions to provide feedback on the facilitators’ performance, clarify any issues they experienced, and ensure that facilitation was performed consistently. Pilot tests were conducted with the trained facilitators to test the task description and scripts for clarity. Based on the facilitators’ feedback, we made a few minor changes to the task description and scripts.

The task focused on a complex, time-constrained decision-making challenge in an emergency situation with no correct answers [64]. We adapted an existing emergency response task [84] by changing its context to a flooding crisis in a fictitious city called Norvos. Norvos is in chaos after severe rainfall has caused major flooding in the city and in surrounding areas. A swift response to this situation is required in terms of rescue efforts and clean-up operations since the main public services, such as fire and rescue, electricity, and water, are nonfunctional or destroyed.

Task goals were outlined in the task description and read out loud by the facilitators. The overall goal was “to suggest help measures to stabilize the situation in Norvos for the next seven days.” For the facilitated treatments, we detailed this overall goal into specific goals for generation and convergence. The goal of idea generation was to generate as many ideas as possible for help measures to stabilize the situation in Norvos for the next seven days. The goal of idea convergence was to clarify and reduce the generated ideas. We further described clarify as ensuring that ideas are understandable for all participants and on a similar level of abstraction, and we described reduce as the merging of same or similar ideas and ensuring that each idea is indeed a help measure. The facilitators were instructed to verify whether participants understood the task goal using the prompt "Do you have any questions?" Subjects appeared to be motivated and engaged to complete the task.

Procedure

Each team first performed a warm-up task to introduce the collaboration technology used in the experiment, ThinkTank by GroupSystems. ThinkTank is an anytime, anyplace collaboration technology that all teams used (instructions regarding technical facilitation were consistent across treatments). The facilitator explained the ThinkTank features and let the teams try them out. Next, participants received the task description, signed the consent form, and filled out the presurvey. Then, facilitators initiated the collaboration process. We had to separate idea generation from idea convergence for AG+/DE–, AG–/DE+, and AG+/DE+ teams in order to apply attention guidance and/or discussion encouragement specifically to the convergence part of idea development (Figure 1). The facilitators applied the same brainstorming technique to guide these teams through 20 minutes of idea generation. Participants could add, edit, reorder, or delete their ideas in a preconfigured ThinkTank generation activity that provided each participant with an empty list. After idea generation, participants filled out a second survey, while the facilitator transferred the lists with generated ideas into the preconfigured ThinkTank convergence activity. During idea convergence, the teams worked for about 30 minutes to reduce and clarify the previously generated ideas. Team members could only view ideas. The facilitator would compose a single preconfigured list of converged ideas depending on the team members' inputs to select, reformulate, and expand the generated ideas. After idea convergence, teams filled out a post-convergence survey.

The collaboration process was executed in a single phase of idea development for AG–/DE– teams as there was no convergence-specific attention guidance or discussion encouragement in this condition (Figure 1). Therefore, these teams worked on the Norvos task for a combined period of 50 minutes. Participants could add, edit, reorder, or delete their ideas or lists in a single preconfigured ThinkTank activity. The facilitators in this condition only answered questions related to the operation of ThinkTank. After completing their task, teams filled out a postsurvey.

Measures

We measured *convergence quality* (*cq*) as a group level externally assessed dependent variable. We first specified task relevance as an inclusion criterion for the assessment of idea quality. The quality of a team's final set of ideas was then determined by the extent to which the relevant ideas were developed to a useful level of detail.

Task relevance describes the ability of an item to lead to an action addressing the problem at hand. An item is considered task-relevant, if it describes an action potentially relevant to address the issues described in the Norvos task (e.g., "Remove debris, mud, and fallen trees from the streets to make them drivable again"). In turn, if an item is unrelated, it would be considered non task-relevant (e.g., "go on vacation"). We coded each item in the final set of ideas to determine whether an item was task-relevant. Two authors coded seven lists with 221 items to assess interrater reliability. The Cohen's kappa for task relevance was 94.38 percent, which indicates a very high level of agreement. We proceeded with the items found relevant in the subsequent analysis of idea elaboration.

Extent of elaboration describes the items' level of detail to clarify the action to address the issues described in the Norvos task. We build upon the dimensions of communicative interaction [95] for assessing the seven dimensions describing in which situation a help measure comes into effect: Why (purpose), Who (participant), What (object), How (form), When (time), Where (place), and If (condition). In its operationalization, extent of elaboration (*eoe*) was measured for each item (li_i) in the final sets of ideas. If the item li_i addressed the dimension d_j, a value of 1 was assigned ($eoe(li_i, d_j) = 1$), otherwise 0 ($eoe(li_i, d_j) = 0$) (Equation [1]). We coded each item in the final set of ideas to determine whether an item addressed a dimension. Cohen's kappa for interrater reliability was 85.40 percent, which indicates a high level of agreement.

$$eoe(li_i, d_j) = \begin{cases} 1 \text{ if } d_j \textit{ is adressed by item } li_i \\ 0 \quad \textit{otherwise} \end{cases}. \tag{1}$$

The values of $eoe(li_i, d_j)$ are then summarized over all list items li_i of the team's idea set and over all dimensions d_j and divided by 7, that is, the total number of dimensions. To accommodate different lengths of idea sets, we divided this number by the length of the idea set (n) in order to calculate convergence quality *cq* (Equation [2]). An example of the assessment is provided in Appendix B.

$$\mathrm{cq} = \frac{\sum_{i=0}^{n-1} \frac{\sum_{j=1}^{7} eoe(li_i, d_j)}{7}}{n}. \tag{2}$$

We measured *process satisfaction* and *product satisfaction* as perception-based dependent variables. *Perceived process satisfaction* describes how pleased participants are with their meeting process. The measure was adapted from [40]. *Perceived product satisfaction* describes how pleased participants are with the outcomes of their meeting. The measure was adapted from Reinig [82]. The constructs *process satisfaction* and *product satisfaction* were measured twice, once after generation and once after convergence, for the three facilitated treatments. All items were measured on the individual level on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) including a "no answer" option.

Reliability and Validity

We followed the common iterative approach to assess reliability and validity. Cronbach's α was found to be good for *process satisfaction* after convergence (α = 0.865) and after generation (α = 0.792). After we dropped one item (see Table 1), the constructs *product*

Table 1. Summary of Measurement Items

Construct	Indicators
Convergence quality	Task relevance Extent of elaboration
Process satisfaction after generation (after convergence[a]) [40]	The team's process of idea generation was efficient. (The team's process of reducing and clarifying was efficient.) The team's process of idea generation was coordinated. (The team's process of reducing and clarifying was coordinated.) The team's process of idea generation was fair. (The team's process of reducing and clarifying was fair.) The team's process of idea generation was understandable. (The team's process of reducing and clarifying was understandable.) The team's process of idea generation was satisfying. (The team's process of reducing and clarifying was satisfying.)
Product satisfaction after generation (after convergence [a]) [81, p. 68]	I am very satisfied with the quality of our ideas. (I am very satisfied with the quality of our final list of help measures.) The ideas reflect our inputs to a great extent. (The final list of help measures reflects our inputs to a great extent.) I feel to a great extent committed to the ideas. (I feel to a great extent committed to the final list of help measures.) I am to a great extent confident that the ideas are correct. (I am to a great extent confident that the final list of help measures is correct.) *I feel to a great extent personally responsible for the correctness of the ideas. (I feel to a great extent personally responsible for the correctness of the final list of help measures.)

*Item was dropped.
[a] For the AG–/DE– treatment the item was reworded into "The team's problem-solving process was . . ."

satisfaction after convergence (α = 0.815) and after generation (α = 0.807) satisfied the conventional criterion of 0.7 for reliability [74]. Unidimensionality was assessed with the Kaiser–Meyer–Olkin criterion (KMO > 0.6), the measure of sampling adequacy (MSA > 0.5), and Bartlett's test (< 0.05) [43]. All values exceeded the common thresholds thus supporting unidimensionality of our constructs.

Convergent and discriminant validity were assessed with a confirmatory factor analysis (CFA) using Smart PLS 3.2.3. We tested convergent validity with the common criteria factor loading (> 0.70), composite reliability (CR; > 0.80), and average variance extracted (AVE; > 0.50). Factor loadings ranged between 0.607 and 0.863 and were above the threshold of 0.70 for all but two items. All factor loadings were significant. CRs ranged between 0.855 and 0.908 and AVEs between 0.546 and 0.663 and therefore were above the common thresholds (Table 2). These results support convergent validity and internal consistency. We tested discriminant validity with the Fornell–Larcker criterion by comparing the square roots of AVE with the correlations between the constructs (Table 2). All square roots of AVE were greater than the interconstruct correlations, which indicates discriminant validity [36]. We also tested the heterotrait-monotrait ratio of correlations (HTMT; < 0.90) which was 0.597 after generation and 0.690 after convergence, thus also supporting discriminant validity [44]. In addition, the loadings of items on each of the intended constructs were higher than on any other construct and also higher than the loadings of any other item not intended for the construct. Taken together, these results provide good support for the validity of our constructs.

As part of the presurvey, we collected information on the four control variables (see Table 3) experience with collaboration systems (technology knowledge), past participation in facilitated meetings (facilitation knowledge), experience with flooding crises (domain knowledge), and knowledge about team members (working history) with one-item questions. An analysis of variance (ANOVA) revealed a significant difference for working history ($F(3) = 3.108$, $p = 0.033$) between treatment groups. We identified one team in which three of four team members had frequently worked together in the past. The same team also scored very high on domain knowledge and the dependent variables. We dropped this group from

Table 2. Results of CFA for Latent Constructs of Satisfaction

Latent construct	CR	AVE	Process satisfaction	Product satisfaction
Process satisfaction after generation	0.855	0.546	**0.739**	
(after convergence)	(0.908)	(0.663)	**(0.814)**	
Product satisfaction after generation	0.878	0.643	0.532	**0.802**
(after convergence)	(0.881)	(0.649)	(0.592)	**(0.806)**

Notes: CR = composite reliability; AVE = average variance extracted; diagonal elements in bold show square root of AVEs; as we conducted two CFAs for the constructs, all values are reported twice, once for after generation and once in parenthesis for after convergence.

Table 3. Means and Standard Deviations of Controls Across Treatments

	AG–/DE+ (*N* = 17) M (SD)	AG+/DE– (*N* = 15) M (SD)	AG+/DE– (*N* = 15) M (SD)	AG–/DE– (*N* = 13) M (SD)
Technology knowledge	1.06 (0.10)	1.07 (0.20)	1.03 (0.13)	1.09 (0.14)
Facilitation knowledge	1.74 (0.40)	1.64 (0.37)	1.68 (0.43)	n/a
Domain knowledge	4.69 (0.50)	4.45 (0.46)	4.68 (0.46)	4.44 (0.31)
Working history	1.39 (0.52)	2.02 (0.85)	1.62 (0.52)	1.93 (0.89)

analysis to avoid any bias due to familiarity among team members. No significant differences for our four control variables were found after we repeated the test ($F(3) = 2.616$, $p > 0.05$).

Results

All data was analyzed with IBM SPSS Statistics 21. For all perception-based constructs, we performed univariate and multivariate outlier analysis as well as missing data analysis to cleanse the data sets [43]. One case with more than 50 percent missing data was excluded from the analysis. Overall, none of the items had more than 3 percent missing data. We imputed missing data with the Expectation-Maximization (EM) method and calculated averaged scales for all dependent variables. All outliers were carefully analyzed, also based on the participants' feedback provided in the survey and kept with the exception of three extreme cases. We assessed normality and homoscedasticity to test assumptions of ANOVA and dependent *t*-tests [43, 86]. Normality was assessed for all dependent variables with z-values for skewness and kurtosis (*z*-values ±2.58) [43]. We applied a squared transformation on the satisfaction constructs, which were found negatively skewed. After transformation, the constructs were reassessed, found normally distributed, so that we deemed the set of variables as satisfying to assume normality. Homoskedasticity was assessed with the Levene's test ($p > .05$) [43]. All variables fulfilled the test assumptions and therefore we proceeded with hypotheses testing. The descriptive statistics are summarized in Table 4.

First, we report on the differences between treatment groups with respect to convergence quality and then report on the changes of satisfaction from generation to convergence within facilitated treatment groups.

We performed two-way analysis of variance (ANOVA) to test the associations of *attention guidance* and *discussion encouragement* as implemented in this study with the team outcome *convergence quality* (C1 and C2). The main effect of *attention guidance* in the ANOVA was significant ($F(1, 56) = 56.620$, $p = 0.000$, partial $\eta^2 = 0.503$). The main effect of *discussion encouragement* was also significant ($F(1, 56) = 5.319$, $p = 0.025$, partial $\eta^2 = 0.087$). There was no significant interaction effect ($F(1, 56) = 0.662$, $p > 0.05$). The two significant main effects suggest that attention guidance as well as discussion

Table 4. Descriptive Statistics: Mean (Standard Deviation)

		Process satisfaction		Product satisfaction	
	Convergence quality	After generation[a]	After convergence[a]	After generation[a]	After convergence[a]
AG+/DE– teams	0.26 (0.06)	5.17 (0.78)	5.78 (0.73)	5.32 (0.82)	5.80 (0.74)
DE+/AG– teams	0.17 (0.06)	5.30 (0.71)	5.92 (0.76)	5.48 (0.67)	5.89 (0.64)
AG+/DE+ teams	0.29 (0.08)	5.03 (1.00)	5.82 (0.62)	5.43 (0.64)	5.73 (0.63)
AG–/DE– teams	0.12 (0.05)	n/a			

[a]Constructs were square transformed.

Table 5. Conjecture Testing Results from ANOVAs

Source	DF	Mean square	F	p-value	partial η^2
ANOVA Dependent variable: *Convergence quality*					
Attention guidance	1	0.251	56.620	0.000	0.503
Discussion encouragement	1	0.024	5.319	0.025	0.087
Attention guidance × Discussion encouragement	1	0.003	0.662	0.419	0.012
Error	56	0.010			

encouragement are positively associated with convergence quality thus supporting C1 and C2. The test statistics are provided in Table 5.

Second, the separation of idea generation from convergence for facilitated teams allowed us to assess whether the provision of attention guidance or discussion encouragement as implemented in this study was associated with changes in satisfaction over time. We performed dependent t-tests to compare the team members' perceived satisfaction after generation with the team members' perceived satisfaction after convergence.

C3 states that facilitated teams will achieve higher process satisfaction after convergence. Process satisfaction was significantly higher after convergence ($t(189) = 12.366$, $p = 0.000$) than it was after generation. This result supports C3. Additional analyses confirm this result across all facilitated teams, that is, for AG+/DE– teams ($t(60) = 6.825$, $p = 0.000$), AG–/DE+ teams ($t(69) = 7.077$, $p = 0.000$), and AG+/DE+ teams ($t(58) = 7.489$, $p = 0.000$). Therefore, the provisions of attention guidance as well as discussion encouragement during convergence are positively associated with process satisfaction over time.

C4 states that facilitated teams will achieve higher product satisfaction after convergence. Product satisfaction was significantly higher after convergence ($t(189) = 8.069$, $p = 0.000$) than it was after generation, thus supporting C4. Additional analyses confirm this result across all facilitated treatments, that is, for AG+/DE– teams ($t(60) = 4.936$; $p = 0.000$), AG–/DE+ teams ($t(69) = 5.430$; $p = 0.000$) and AG+/DE+ teams ($t(58) = 3.548$; $p = 0.001$). Therefore, the provisions of attention guidance as well as of discussion encouragement during convergence are positively associated with product satisfaction over time.

Discussion

Our study advances research on idea convergence with two main contributions. First, our results provide preliminary support for the value of focused and purpose-oriented structuring interventions to improve convergence quality. With this we contribute to a call to examine the various activities of creative idea development and to explore factors that influence these activities and their outcomes [54]. We propose attention guidance and discussion encouragement as facilitation components that can be used in structuring interventions to support a team's collaborative activities during convergence. Our findings suggest that attention guidance is associated with higher convergence quality, regardless of whether it is combined with discussion encouragement. We found the same positive association for discussion encouragement, regardless of whether it is combined with attention guidance.

Second, we found that teams reported higher levels of process and product satisfaction after convergence than after generation. This finding challenges past research [20] reporting that satisfaction levels drop after generation activities. In their study, idea generation was directly followed by idea organization. Subjects reported the lowest satisfaction levels at a "point at which the group realiz[ed] that it can converge on a manageable set of issues to rank" [20, p. 57]. This implies that several reduction activities were executed during idea organization, which might have led to information overload and therefore to lower satisfaction. Declining satisfaction levels are problematic because they might lead teams to be less motivated to produce high-quality outcomes or even to abandon their efforts. Therefore, our finding that facilitated teams' satisfaction is higher after convergence than after generation activities is encouraging as it strengthens the likelihood of sustained engagement in later idea development activities such as organization and evaluation.

Below we discuss what associations we found for our implementations of the two facilitation components (i.e., attention guidance and discussion encouragement) and explain why these may have been associated to higher convergence quality.

Insights on Attention Guidance

Our findings revealed that our implementation of attention guidance is positively associated with convergence quality. We argue that a key reason is that attention guidance decomposes the complex task of idea convergence into distinct steps and defines a temporal and logical relationship between these steps. This converts the convergence task into a structured procedure [56] consisting of a sequence of activities [93]. We further argue that attention guidance addresses at least three purposes that may be associated with convergence quality: (1) a coordination strategy to manage the team's work, (2) an information processing strategy, and (3) a repeated goal specification.

From a *coordination strategy* perspective, attention guidance defines time allocations for steps and enforces these time limits during execution. This sets upper and lower bounds on the amount of time that can be spent on ideas. For example, facilitators in the AG treatments used specific prompts, for example, "Please select a help measure in the next 30 seconds." Moreover, the convergence task is decomposed into reduction efforts and clarification efforts to lessen the complexity of each step. We implemented reduction by first asking subjects to pick one idea out of their assigned idea list and afterward asking them to clarify the idea. With coordination efforts in the hand of the facilitator, subjects did not have to determine how to organize their convergence process. We argue that this decreased subjects' cognitive load, because they could focus their efforts on processing information to execute the actual convergence task rather than on coordination and team monitoring processes [63]. Teams that spend more resources on their actual task are more likely to produce high quality deliverables [85] given (a) that team members are motivated to apply such additional cognitive resources to task-relevant issues, and (b) that idea convergence is time-constrained so that compensation over time is not possible. Also, enforcing time limits makes it more likely that subjects exert a minimum amount of cognitive effort to each idea and avoid running out of time when they get stuck on a single idea. Thus, we argue that this implementation of attention guidance makes it more likely that subjects may process a greater breadth of ideas from the initial idea set, which would have a positive effect on convergence quality.

From an *information processing strategy* perspective, attention guidance divides the entire initial set of generated ideas into separate idea lists of a specific size that are considered in separate rounds. Then, rather than instructing each subject to process all generated ideas, this implementation of attention guidance assigns separate idea lists to subjects for parallel processing in each round. For example, facilitators in the AG treatments used specific prompts, such as, "I will assign a list with ideas to each of you" or "Now we swap lists." Chunking reduces information overload [42] and we argue that this strategy reduces the amount of information that each subject needs to process at a single point in time. Processing power would be "wasted" if every subject had to process the entire initial set of generated ideas at once; rather, idea lists are processed by a limited number of subjects, depending on the number of rounds. Research on decision making shows that individuals make optimal decisions when exposed to six to ten options [78]. Limiting the number of ideas per list ensures that all ideas are considered when a subject processes his or her assigned list. Thus, we argue that this will increase chances that all ideas get processed thoroughly to be selected for inclusion in the final convergence list, thus increasing convergence quality. In contrast to coordination strategy, which helps the team to allocate time and organize the convergence activity in general, the information processing strategy specifically addresses the task of how to process and therefore reduce and clarify subsets of ideas.

From a *goal specification* perspective, attention guidance also includes instructions to repeatedly remind subjects to focus on the task at hand during the convergence process. This helps to limit nontask behavior [1] and to keep information processing on topic [93]. In our implementation of attention guidance, the facilitator repeatedly prompted teams to focus on the goals of reduction and clarification. Concerning reduction, subjects were prompted to summarize similar or identical ideas ("Is this the same help measure?") and to make sure that each idea is really a help measure ("Did you think of a specific help measure, which we can add to the list?"). Concerning clarification, we used prompts to ensure ideas are well specified ("Could this lead to misinterpretation?") and on a similar level of abstraction ("Could you specify in a bit more detail?"). Such recurrent goal specifications help team members to identify potential misfits among explicated ideas [47] and avoid shallow processing of exchanged information [83], which we expect will induce higher convergence quality.

Insights on Discussion Encouragement

Our findings also revealed that discussion encouragement as implemented in our study positively correlates with convergence quality. We submit that a key reason is that discussion encouragement facilitates the communication of distributed knowledge in these convergence teams. We argue that discussion encouragement addresses at least two purposes that may be associated with convergence quality: (1) stimulation of conversations for idea clarification, and (2) stimulation of prolonged discussions for the combination of ideas.

From an *idea clarification* perspective, our implementation of discussion encouragement initiated communication with prompts ("Please have a conversation to reduce and clarify the list of ideas") and ensured that communication is audible by the members of the discussion group ("Please speak in a normal volume so that everyone can hear"). With prompts to stimulate conversations, the facilitator triggers clarification of explicated ideas by the idea creators. This is necessary because other team members might interpret textual descriptions of explicated ideas differently. Even if the idea creator has a clear understanding of the idea, the knowledge that needs to be externalized into a written idea description consists of parts that are explicit (knowledge that can be codified) and implicit (knowledge that is difficult to transfer) [79]. With triggered communication, subjects are given opportunities to externalize the implicit part of an idea to also fully transfer the inherent intention of the idea. This way, we argue, the subjects become aware of the similarity or dissimilarity of their understanding of an idea and can consequently improve the textual description of an idea. Convergence quality should improve due to the additional details that emerge through group clarification. Yet explicating an idea creator's full understanding of an idea does not necessarily lead to a synthesis of (similar) ideas.

From an *idea combination perspective*, convergence teams require interventions that motivate subjects to discuss ideas [54]. In our implementation of discussion encouragement, we stimulated prolonged discussions concerning the convergence task. Furthermore, we prompted subjects to make knowledge dispersed among individual group members [46] regarding the ideas under consideration available for combination, for example, "You now have the opportunity to discuss the ideas." Combination describes a knowledge conversion process in which multiple sources of externalized knowledge, for example, in the form of textual idea descriptions, get synthesized [71, 72]. In the context of our implementation of discussion encouragement, we stimulated individuals to discuss ideas that were not necessarily their own. Encouraging subjects to discuss ideas with others can provide the necessary external cues to access concepts in long-term memory [33] and make this knowledge available for potential synthesis. Therefore, subjects other than the idea creator could also hold or develop explicit and implicit knowledge related to ideas. Encouraging discussions in such groups allows for making dispersed knowledge available for information processing and therefore combining ideas into more useful or novel ideas [54], thus improving convergence quality.

Implications for Research

There are two main implications for researchers who investigate technology-supported collaboration processes. First, our findings demonstrate that convergence outcomes differ for teams that received purposeful, carefully delineated and compartmentalized structuring interventions. We suggested attention guidance and discussion encouragement as two facilitation components for idea convergence. We theorized how the provision of coordination strategy, information processing strategy, and goal specifications as part of attention guidance as well as the stimulation of idea clarification and idea combination as part of discussion encouragement are strongly associated with convergence quality. Thus, researchers can use our exploratory findings to investigate different manifestations of attention guidance (such as variations of interventions into information processing or of an emphasis on clarification versus reduction of ideas), or discussion encouragement (such as varying the extent of prolonged discussions for idea combination).

Second, given the significant improvements in satisfaction that are associated with distinct interventions into the convergence activity, our study demonstrates that it is important for researchers to conceptually distinguish between collaboration activities when investigating the effects of interventions. This allows researchers to isolate the effects of structuring interventions on outcome variables that are important for the collaboration activity concerned. Thus, rather than studying idea development holistically, researchers need to detail the discrete activities involved and measure specific outcome variables related to these activities. This also implies that measurements should be performed at certain times during idea development and not just at the point that the entire process has been completed.

Implications for Practice

Our findings support the notion that idea convergence is an important activity in settings where idea development is critical. Further, teams engaged in purposefully facilitated idea convergence might achieve higher idea quality and, compared to idea generation, experience increased satisfaction.

The current empirical setting has served well for a detailed exploration of convergence due to the ability to isolate convergence activities and facilitation components while controlling for other variables such as time, task type, task complexity, team size, skills, and collaboration technology used. Our empirical setting is similar to various complex, time-constrained situations with a sense of urgency where teams need to reduce and clarify a limited number of ideas from a larger idea set, including but not limited to military course of action analysis, incident response planning and decision making, or idea selection in innovation contests. In such situations, teams or community managers are likely to face similar challenges in which convergence techniques can help to effectively converge on ideas in limited amounts of time.

Our findings are relevant for managers of collaboration processes, such as community managers, team leaders, or professional facilitators, but also for team members themselves who can monitor group dynamics and progress for improved collaboration outcomes. While it can be argued that increasing convergence quality through attention guidance and discussion encouragement is important for any team that needs to identify and select the most promising ideas from a collection of brainstorming results, it is of particular importance when the outcomes of the convergence activity need to be passed on for further consideration and development. In these cases, the resulting idea set represents not only a shared artifact within a team. It also functions as a boundary object [88] that has to be self-explaining [57] for the other team that will be responsible for further steps in the idea development process. Therefore, teams need to develop ideas to a sufficient level of detail, so that they can be handed on to mobilize others for further idea development, selection, or action [62], since in this case the original authors of the deliverables are not accessible anymore to provide contextual information. Such a scenario is especially prevalent in open collaboration crowdsourcing environments where different members of a dynamic crowd may work on artifacts at different stages of development.

Limitations

As with any study using experimental methods, our design is limited in its simulation of a real-world setting. However, the subjects' limited time, resources, prior exposure to the task context plus the random assignment to teams mimic small, ad hoc teams with few past work relationships as closely as possible. Future research could study convergence in other setups, such as teams of different sizes, prior experiences, or sustained work relationships.

The starting points of the convergence activity were lists of ideas that each team had generated in a preceding facilitated idea generation activity. This carries a potential risk because some teams might have generated only a limited set of ideas to converge on. Future research could determine whether attention guidance or discussion encouragement interventions are related to similar effects when each team uses an identical standard set of ideas as a starting point for convergence. Such a scenario would be representative of a crowdsourcing setting where a small number of participants are asked to process ideas generated by other participants.

Also, our experiment was limited to a sequence of two collaboration activities, generation and convergence. We did not investigate subsequent phases of the idea development process. Future research could study the effects of convergence interventions on subsequent phases of collaboration, for example, to what extent the development of ideas makes it easier for teams to reach consensus when they are making their decision.

Finally, repeatedly measuring satisfaction may have led to social desirability issues. Having been exposed once to the satisfaction measure may have predisposed the respondents to think about these issues, resulting in an increase in satisfaction, regardless of any impact of the attention guidance and discussion encouragement interventions. While informal feedback from the subjects did not indicate that this was the case, future research could replicate our study and only measure satisfaction after the convergence activity. Any difference in the findings of the two investigations can be tested for significance.

Conclusion and Future Research

Convergence is a critical team activity that typically follows brainstorming. Little is known about how structuring interventions to facilitate convergence are associated with differences in outcome quality. To the best of our knowledge, our exploratory study represents the first detailed investigation to gain a deeper understanding of structuring interventions and their effects during team-based, IT-supported idea convergence. Our findings suggest that improved convergence quality is positively correlated with the two proposed facilitation components of attention guidance and discussion encouragement. Moreover, we found that satisfaction increased in facilitated teams from generation to convergence.

Future studies are required to test the generalizability of the proposed facilitation components and their relationships to the same or other phenomena of interest. In this study, we focused on the extent of elaboration as a dimension of idea quality. In the future, we intend to study how facilitated convergence may correlate with other dependent variables, such as shared mental model creation, need for cognition, or the effectiveness of ideas in converged sets. Idea effectiveness, in particular, is relevant, because individuals in idea development settings are often not able to select the best ideas [39]. Consequently, successful facilitated convergence should increase the probability that team members pick and clarify good ideas so that subsequent evaluation can be done on a set of high-quality, elaborated ideas that are more likely to solve a specific task problem.

Our findings challenge past studies regarding process and product satisfaction in teams going through a convergence activity thus justifying more detailed investigation. Future research can extend the scope of the collaboration activities beyond convergence to see whether participants' satisfaction continues to increase, remains constant, or decreases. Such studies could differentiate between the same team continuing to work on the converged set of ideas, for example, in an evaluation activity, and a different team that receives the converged list as a boundary object. Future research can also extend the scope from small teams converging during a complex decision-making process under time constraints to a larger team or crowd that generates sizable idea sets on which they need to converge. It would be useful to determine to what extent the facilitation components, as implemented in our study, are scalable, meaning whether they also benefit larger groups working for extended periods of time.

Finally, recent collaboration technology research suggests that there is merit in automated facilitation in the form of embedded scripts that offer participant instructions [18]. It would be interesting to implement attention guidance and discussion encouragement scripts into collaboration technology and test whether automated scripts have comparable correlations with convergence outcomes.

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Appendix A: Description of Convergence Interventions

We based our implementation of the attention guidance and discussion encouragement facilitation components on the thinkLets design pattern language for collaborative work practices [24, 55]. ThinkLets are named, scripted facilitation procedures that invoke a pattern of collaboration, in our context during idea convergence. A thinkLet specifies the rules and technology capabilities that team members work with to effectively execute their work [25]. These codified prescriptions are domain independent and may be executed using different collaboration technology platforms. ThinkLets have been extensively used in practice to successfully improve the collaboration outcome of teams [26].

For AG+/DE– teams we based our instructions on a thinkLet called "FastFocus" [17], which offers attention guidance. With FastFocus, the facilitator distributes all brainstorming ideas among the team so that each team member only sees a subset of the ideas. Then, the facilitator calls on team members in turn to select or further develop an idea from their subset that they believe is worthy of further consideration. During this process, the facilitator specifically guides team members to focus on task relevance, avoid redundancies, and to generalize or specify the idea to an appropriate level of detail. The facilitator adds each idea to the list of converged ideas that everyone can see. After each team member has had one turn to contribute an idea to the converged list, the sets of brainstorming ideas are reassigned to different team members and the facilitator initiates a next round. This process continues until no participant wants to add any more ideas to the converged list.

For AG–/DE+ teams we based our instructions on a thinkLet called "SelfSifter," which offers discussion encouragement. SelfSifter affords unrestricted team conversations to develop a converged idea set. With SelfSifter, the facilitator advises the team to discuss the brainstorming ideas in order to identify a collection of most promising ideas. However, the facilitator does not provide any guidance on how to execute the task; the team members can determine this themselves. The facilitator sets and monitors the time available and records each idea that the team wants to add to the list of converged ideas.

For AG+/DE+ teams we based our instructions on a thinkLet called "TreasureHunt," which offers both attention guidance and discussion encouragement. This thinkLet follows the attention guidance structure of the FastFocus thinkLet and in addition stimulates discussion about ideas. First, the facilitator creates subteams and assigns each subteam a subset of the brainstorming ideas. Next, subteams are asked to discuss their ideas in order to select two ideas that they want to add to the converged set of ideas. Then, the facilitator calls on each subteam in turn to share the ideas that they would like to see considered and be added to the convergence list. Similarly to FastFocus, the facilitator specifically guides team members to focus on task relevance, avoid redundancies, and to develop the idea to an appropriate level of detail. After each subteam has had a turn to contribute ideas to the converged list, the sets of brainstorming ideas are reassigned to different subteams and a new round is initiated. This process continues until no subteam wants to add any more ideas to the converged list.

Appendix B: An Example of the Assessment of Convergence Quality

Item label	c1 (WHAT)	c2 (HOW)	c3 (WHO)	c4 (WHERE)	c5 (WHY)	c6 (WHEN)	c7 (IF)	$\frac{\sum_{j=1}^{7} eoe(li_i, d_j)}{7}$
1. Organize fundraising [what] at a national [where] and if necessary international level [if] through aid agencies [who]	1	0	1	1	0	0	1	4/7
2. At first [when] a first-aid station should be established [what] to provide for injured [why] more quickly	1	0	0	0	1	1	0	3/7

$cq = \frac{\frac{4}{7}+\frac{3}{7}}{2} = \frac{7}{14} = 0.5$