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Beyond Productivity Loss in Brainstorming Groups: The Evolution of a Question

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BEYOND PRODUCTIVITY LOSS IN BRAINSTORMING GROUPS: THE EVOLUTION OF A QUESTION

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Abstract

Why do interactive brainstorming groups perform so much worse than individuals working as nominal groups? This was the original question, which stimulated three decades of research, as described in this chapter. Three different phases in brainstorming research can be distinguished, each of which answered a new question. In Phase 1, interactive brainstorming groups were compared with nominal groups with respect to the quantity of ideas produced, and production blocking (having to take turns to express ideas) was identified as the major cause of productivity loss. But why did production blocking have such devastating effects on idea generation? To answer this question, a cognitive model was developed and tested in Phase 2. Blocking was shown to lead to cognitive interference. But at the same time, evidence indicated that exchanging ideas could have cognitive stimulation effects. This opened the possibility that with blocking effects removed, exposure to the ideas of others could increase idea quality as well as quantity. Therefore, in Phase 3, research attention shifted to idea quality. It was found that a deep exploration of categories of ideas led to higher idea originality. To assess whether participants were able to identify their best ideas, we added idea selection to idea generation and found that people prefer ideas that are feasible to those that are original. The outcomes of each of these phases have implications for work in other areas, including group performance, human memory, and creativity. These implications, as well as the implications for practice, are discussed.

1. INTRODUCTION

For the past decades, organizations have increasingly relied on “teamwork,” a tendency that is likely to persist in the decades to come. This practice is based on the assumption that people working together in groups benefit from their interaction and outperform people who are working alone (e.g., [Cohen & Bailey, 1997](#); [Dunbar, 1997](#)). This belief is particularly pervasive in the area of group creativity. Some 80% of people believe that they can generate more ideas and more creative ideas when working in groups than when working alone ([Paulus et al., 1993](#); [Stroebe et al., 1992](#)), and creative idea generation is commonly performed in groups. For example, designers use group sessions to generate design solutions ([Sutton & Hargadon, 1996](#)), top managers use team sessions to generate ideas on how to improve the functioning of their companies ([West & Anderson, 1996](#)), and researchers generate hypotheses in groups ([Dunbar, 1997](#)).

Brainstorming, which was formally developed by the advertising executive [Osborn \(1953, 1957, 1963\)](#), is one of the most popular ways to produce creative ideas in groups. It is based on two principles: *deferment of judgment* and *quantity breeds quality*. Osborn claimed that use of these principles would

help to free the creative potential inherent in groups. Deferment of judgment requires a clear separation of idea generation and idea evaluation. Criticism of one's own ideas, as well as of ideas of others, is not allowed during the idea generation phase. Because original ideas often are unusual or even seem slightly bizarre, they might easily fall victim to self-censure and censure from others. Ruling out criticism should therefore increase the quantity of ideas produced and hence, according to the second principle, also idea quality. Furthermore, by emphasizing quantity of ideas as the desired outcome, Osborn hoped to further reduce group members' tendency to be critical of the ideas that were produced. From these two principles, Osborn derived the four rules of brainstorming:

1. Criticism is ruled out
2. Free-wheeling is welcomed
3. Quantity is wanted
4. Combinations and improvements are sought

Osborn claimed that if these rules were adhered to, "the average person can think up twice as many ideas when working with a group than when working alone" (Osborn, 1957, p. 229). Empirical studies that compared the productivity of interactive groups with that of the same number of individuals working alone (i.e., nominal groups), whose ideas were combined into a group product by the experimenter (with ideas mentioned several times counted only once), have consistently failed to support this assumption (for reviews, see Diehl & Stroebe, 1987; Mullen et al., 1991). As Mullen and colleagues (1991) concluded from a meta-analysis of 20 brainstorming studies, nominal groups do not only produce substantially more (nonredundant) ideas than interactive groups, but they also produce a substantially greater number of high-quality ideas.¹ Further, the productivity loss of interactive groups as compared to nominal groups increases rapidly with group size.

In this chapter, we will review three decades of research stimulated by these findings. In our review, we highlight how progress on one research question has led to the development of new questions. Based on the questions addressed, the approach taken, and the methodology employed, brainstorming research can be categorized into three distinctive phases. These three phases, with the main research question, measures, and methodology used, are summarized in Table 4.1. Each of the three phases also has connections to and implications for work in other areas, such as the group

¹ Quality of ideas is usually based on some combination of ratings of originality (the degree to which an idea is considered innovative) and feasibility (the extent to which an idea is considered relevant to the topic and practically feasible). The correlation between quantity of ideas and number of high-quality ideas is typically so high (e.g., $r = 0.82$ in Diehl & Stroebe, 1987, Experiment 1; $r = 0.69$ in Parnes & Meadow, 1959) that researchers often use quantity of ideas as their only indicator of productivity.

Table 4.1 Three phases of brainstorming research

Phase	Main research question	Paradigm	Main dependent variables	Connected with
Productivity	How can the productivity loss of brainstorming groups be explained?	Comparing group performance with pooled individual performance (nominal groups)	Productivity (number of ideas)	Group performance literature (social facilitation, social loafing/free riding)
Cognitive	How does group interaction affect cognitive processes?	Simulating aspects of group interaction with individual participants	Content of ideas (categorization)	Cognitive psychology, memory models, groups as information processors
Creativity	What determines the level of creativity of groups (and individuals)?	<ol style="list-style-type: none"> 1. Group versus individual performance on idea selection 2. Priming procedures 	Quality of ideas (originality, feasibility)	Creativity literature; social cognition

performance literature, cognitive psychology (e.g., work on free recall), and the work on individual and group creativity (see Table 4.1).

In Phase 1, the main research question was *why groups incur productivity loss*. In other words, the focus was on motivational, social, or cognitive causes of the productivity loss in interacting brainstorming groups. The approach taken was to compare groups and individuals in nominal groups with respect to the quantity of ideas generated, and early hypotheses were mainly derived from the work on social loafing, free riding, and social facilitation. Although the topics used in most of these studies were socially relevant, participants were not led to believe that their ideas would be used by outside institutions to solve social problems. With the identification of production blocking (i.e., the fact that group members may have to wait for their turn before reporting an idea) as the main cause of this group productivity loss (e.g., Diehl & Stroebe, 1987, 1991), new research questions were raised.

These were addressed in Phase 2, which focused on the question *how the group context affects group members' cognitive processes*. First, a theory was needed that could account for the impact of production blocking on idea generation. Extending the SAM (Search of Associative Memory) model of Raaijmakers and Shiffrin (1981), Nijstad and coworkers (Nijstad, 2000; Nijstad et al., 2002, 2003) developed a cognitive theory of idea generation (i.e., SIAM; Search for Ideas in Associative Memory). Because this theory also predicted that exposure to ideas of other group members could potentially result in stimulation, a new research line focused on mutual stimulation within idea-generating groups (Nijstad et al., 2002; Rietzschel et al., 2007). In this phase, not only idea quantity was assessed, but also the content of ideas, to allow for a more fine-grained analysis of cognitive processes underlying idea generation. The approach often taken was to simulate certain aspects of group interaction using individual participants, and see how this affected the quantity and content of the ideas they generated.

Although the brainstorming procedure explicitly emphasizes idea quantity, this strategy has always been intended as a creativity-enhancing technique with the ultimate aim of brainstorming sessions to lead to a few very good ideas that could be further developed and implemented. Having concentrated mainly on the quantitative aspects of idea generation during Phases 1 and 2 (assuming that quality was an automatic by-product of quantity), researchers finally began to focus on idea quality in Phase 3. In this phase, two types of questions became pertinent. First, although it was known that quantity leads to quality, very little was known about the *processes* that lead to the generation of good ideas. Therefore, in this third phase, the research on brainstorming was connected more explicitly to the creativity literature. Second, because the ultimate goal of brainstorming is the identification (and implementation) of a few innovative ideas, it was important to discover *what happened after idea generation*. Therefore, research

began to focus on groups' efficacy in recognizing and selecting good ideas as an important determinant of their performance (Faure, 2004; Putman & Paulus, in press; Rietzschel et al., 2006, 2010).



2. PHASE 1: IDENTIFYING THE CAUSES OF PRODUCTIVITY LOSS IN BRAINSTORMING GROUPS

2.1. Free riding or social loafing

Because Osborn considered the suppression of self- and other criticism as a particularly important ingredient of his brainstorming procedure, it was a plausible hypothesis that the poor performance of interactive brainstorming groups was due to failure of the brainstorming instructions to reduce social inhibition. In other words, brainstorming groups were not productive because the brainstorming procedure failed to stimulate uncensored idea exchange. This explanation would be consistent with the literature on social facilitation and inhibition effects (e.g., Zajonc, 1965). This work had shown that the presence of others can be associated with evaluation (e.g., Cottrell, 1972) and inhibits performance on tasks that are not well-learned, or in which a nondominant response has to be emitted. Because creative tasks require the generation of nondominant (i.e., creative, unusual) responses, the presence of other group members may lead to social inhibition.

Support for this hypothesis came from a study by Collaros and Anderson (1969), who manipulated the perceived expertise of group members in brainstorming groups. These authors assumed that group members would be inhibited in presenting their ideas if they believed other group members to possess more problem-relevant knowledge than they themselves did. Consistent with expectations, group members were least productive when they were led to believe that all other group members had greater expertise than they themselves, and most productive when everybody felt equally competent. However, this pattern of results was not replicated by Maginn and Harris (1980), who used a different strategy to induce social inhibition. In their study, half of the participants (all of whom engaged in an individual brainstorming session) were led to believe that they were being observed and evaluated by judges through a one-way mirror; this manipulation should increase evaluation apprehension and therefore lead to social inhibition. The other half of the participants was not given such instructions. Maginn and Harris (1980) used two rather uninvolved and uncontroversial discussion problems, namely the thumbs problem (what would be the benefits and difficulties if people found that they had grown an extra thumb) and the energy conservation problem (what could be done to

conserve energy; in the 1980s, energy conservation was not a problem that would have deeply concerned American students). Contrary to expectations, the (purported) presence of observers failed to reduce brainstorming productivity.

A possible explanation for this inconsistency can be derived from the economic theory of group productivity suggested by [Stroebe and Frey \(1982\)](#). This theory is an application of [Olson's \(1965\)](#) theory of public goods to group performance. Economists distinguish private goods, the use of which can be restricted to those who paid for (or contributed to) the production of the good (e.g., a cup of coffee, a car), from public goods, which can be enjoyed by everybody, regardless of whether they made a contribution to the creation of the good (e.g., clean air; military victory). With public goods, there is always a temptation to free ride on the efforts of others, without contributing one's fair share to the costs. The same problem can arise in groups, where group products (e.g., the cleanliness of a shared apartment) can be a public good. According to the economic theory of group productivity of [Stroebe and Frey \(1982\)](#), the temptation to profit from the efforts of other group members without making a contribution oneself (i.e., free riding) is determined by three factors: (1) the *cost* of the individual contribution, (2) the perceived *identifiability* of individual contributions, and (3) their perceived *dispensability*. The temptation to free ride will be greatest if group members perceive their contribution as costly (e.g., effortful), if they think that individual contributions are not identifiable, and if they feel that their contribution does not really add much to the group product and is therefore dispensable. Thus, if the group has no way of knowing whether an individual group member contributed to the group product, members will be tempted to free ride on the effort of others, particularly if a potential contribution would be costly. However, even if individual contributions are identifiable and not very costly, group members might not be motivated to contribute to a group product if they believe that their own contribution is not really needed (i.e., dispensable). Differential ability is one of the many reasons why group members might feel that they cannot effectively contribute to the group product. For example, if one sees oneself as the only dummy in a group of mathematical wiz kids, one might not try hard to contribute to a mathematical problem put to the group.

According to this theory, the studies of [Collaros and Anderson \(1969\)](#) and [Maginn and Harris \(1980\)](#) manipulated different determinants of free riding. In attempting to manipulate inhibition by creating the perception of differential expertise, [Collaros and Anderson \(1969\)](#) may actually have manipulated dispensability and thus created a temptation to free ride ([Stroebe, 1981](#)). Those group members who had been led to believe that they knew much less about the topic than all the other members of their group are likely to have felt that their contributions were dispensable. They would therefore have

been less motivated to make a contribution than participants who believed that they were as competent as other group members.

In contrast, [Maginn and Harris \(1980\)](#) attempted to increase inhibition by increasing the identifiability of individual contributions. However, these researchers may have failed in this attempt because participants in individual brainstorming sessions already expect that their performance will be monitored by the experimenter. Informing some of them that, in addition, they would be observed by judges may therefore have failed to increase their feeling of being identifiable (and hence did not increase the temptation to free ride). This explanation would be consistent with the literature on social loafing and free riding that has shown that individuals reduce their efforts when they are (or believe that they are) working in groups, because individual contributions are less identifiable and more dispensable (i.e., less effective) when working in groups ([Ingham et al., 1974](#); [Kerr & Bruun, 1983](#); [Latané et al., 1979](#)). Furthermore, social loafing effects have also been demonstrated using a brainstorming paradigm (e.g., [Harkins & Jackson, 1985](#)), and social loafing or free riding can potentially account for the finding that the productivity loss in brainstorming increases with group size: identifiability and indispensability decrease with increasing group size.

To assess whether the productivity loss of interactive brainstorming groups was indeed due to free riding, [Diehl and Stroebe \(1987, Experiment 1\)](#) conducted a study in which they manipulated perceived identifiability in individual as well as group brainstorming sessions. They did this by telling individual or group brainstormers that their contributions would be either inspected individually (individual assessment instructions) or pooled into a group product (collective assessment instructions). Participants had to discuss a problem that was important to German students at that time, namely how to improve the relationship between foreign (guest) workers and the German population. Compared to collective assessment instructions, individual assessment instructions increased both the quantity and quality of ideas produced, which suggested that free riding was responsible for part of the productivity loss of interactive brainstorming groups. However, the impact of type of session (individual vs. group idea generation) was much greater (accounting for more than 83% of the variance) than that of assessment instructions (inspection of individual vs. group products; accounting for just under 8% of the variance). Thus, a substantial effect of individual versus group brainstorming remained, even when controlling for these differential assessment expectations. This suggested the presence of one (or several) other factor(s) that had a more powerful impact on group productivity than the temptation to free ride. In retrospect, the finding that free riding played only a minor role as determinant of the productivity loss in brainstorming groups is quite consistent with the economic theory of work motivation in groups, because generating ideas in groups does not require a great deal of effort and is generally perceived to be quite enjoyable (e.g., [Nijstad & Stroebe, 2006](#)).

2.2. Social inhibition

With free riding ruled out as a major explanation of the production loss observed in brainstorming groups, Diehl and Stroebe (1987) considered the possibility that social inhibition might be the major reason for this decrease in productivity. As mentioned before, the failure of the Maginn and Harris (1980) study to find social inhibition effects could have been due to the fact that the expectation to be evaluated by the experimenter already created high levels of social inhibition in their participants and that adding a second evaluation through judges may not have increased evaluation apprehension even further. Alternatively, it is also possible that the nature of the problems used by Maginn and Harris (1980) prevented social inhibition. It seems plausible that individuals will be most likely to censor their responses if they fear that their answers may disclose undesirable or even embarrassing aspects of themselves (e.g., lack of knowledge, ideological biases). Discussing problems such as the thumbs problem or the energy conservation problem might elicit little social inhibition.

To test these explanations, Diehl and Stroebe (1987, Experiment 2) essentially replicated the Maginn and Harris study, but manipulated the nature of the brainstorming topic as an additional variable. Participants, who brainstormed individually, either had to discuss uncontroversial topics (e.g., how to improve entertainment programs on TV) or controversial topics (how to reduce the number of foreign guest workers in Germany). This topic was controversial because the desire to reduce the number of foreign workers in Germany was part of the right-wing agenda and thus alien to the mostly liberal student body at Tübingen University. As in the Maginn and Harris (1980) study, social inhibition was manipulated by either telling participants that they would be evaluated by judges through a one-way mirror or not giving them these instructions. Diehl and Stroebe expected an interaction between the nature of the brainstorming topic and social inhibition, with the social inhibition manipulation reducing productivity only for the controversial, but not the uncontroversial topic. Instead, their manipulations resulted in two main effects: Participants produced fewer ideas on controversial than uncontroversial topics, and when believing that they would be observed rather than not observed.

These findings, although inconsistent with those reported by Maginn and Harris (1980), raised the possibility that social inhibition was responsible for the productivity loss in brainstorming groups. To assess this possibility, Diehl and Stroebe (1987, Experiment 3) conducted a further study in which they crossed the type of brainstorming session (i.e., group vs. individual) with a manipulation of social inhibition. High inhibition was created by having participants in both types of sessions video-taped and informed that these tapes would be shown in their social psychology class as part of the lecture on brainstorming. The discussion topic was the guest worker

problem they had used in their first experiment. If social inhibition was responsible for the productivity loss in interacting brainstorming groups, there should be an interaction between the type of session and the social inhibition manipulation. Under high social inhibition, the effect of type of session should be weakened or even eliminated. Instead, the manipulations resulted in two main effects, one for social inhibition and one for type of session. The interaction did not even approach significance. Furthermore, type of session (individual or group) accounted for more than 70% of the variance in brainstorming productivity, suggesting that even if social inhibition accounted for part of the productivity loss in brainstorming groups, the impact of this variable was minimal compared to that of type of session.

2.3. Production blocking

An alternative explanation of productivity loss in brainstorming groups was put forward in an early review of brainstorming research by Lamm and Trommsdorff (1973). They pointed out that brainstorming performance is inevitably limited by the fact that group members have to take turns in expressing their ideas. After all, if all group members tried to talk at the same time, nobody could understand anything. Social norms that prescribe turn-taking and forbid that more than one group member can speak at any time are therefore useful regulators of verbal interaction in groups. Members who want to make a verbal contribution have to wait until the person speaking has finished. Lamm and Trommsdorff hypothesized that this type of blocking was the main factor responsible for the productivity loss in interactive groups.

Because production blocking cannot be eliminated in naturally interacting groups, Diehl and Stroebe (1987, Experiment 4) tested this hypothesis by inducing blocking in individual brainstorming sessions. Participants were placed in four separate rooms to brainstorm individually and to speak their ideas into a microphone. In each of the rooms there was a display with four lights, one green and three red. Participants were (correctly) informed that each of the lights represented one group member sitting in one of the rooms and that a red light indicated that one of the group members was talking. They were instructed to talk only when their green light was on. The lights were controlled by acoustic sensors, so that when one of the four participants started talking, red lights would be switched on in the other rooms, preventing the other three participants from speaking, until this participant had stopped. Thus, the lights guaranteed that only one participant would talk at any moment, and thus created the same type of blocking that operates in interactive groups (Condition 1). In a second experimental condition, participants were provided with earphones so that, in addition to being blocked by the red light, they could also hear the ideas presented by each of the other participants (Condition 2). A third group (Condition 3) had the

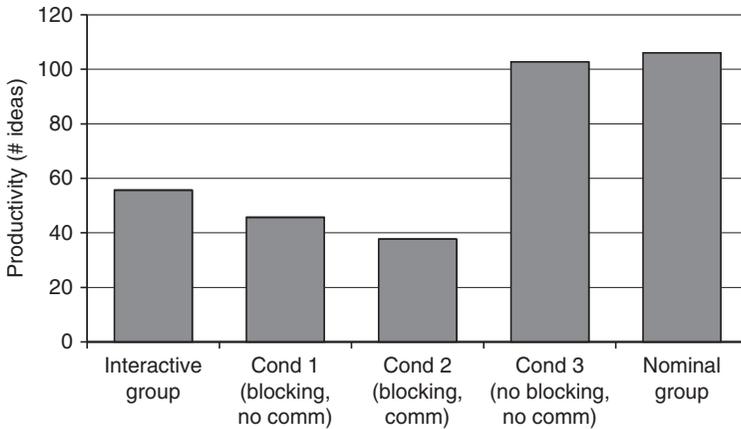


Figure 4.1 Number of ideas suggested by nominal versus real four-person groups under blocking and nonblocking conditions (from Diehl & Stroebe, 1987).

set of lights and was also informed about their function. However, these participants were told to disregard the lights, which were left operating throughout the session, and to talk even when their red light was on. This condition was included as a control, in case the lights had any other effect (apart from blocking; e.g., that these lights are distracting). As further control groups, the experiment also contained regular interactive and nominal brainstorming groups. As we can see from Fig. 4.1, blocking resulted in a major decrease in brainstorming productivity. Participants in conditions that involved blocking (Conditions 1 and 2 and the interactive group control condition) produced only half as many ideas as participants who brainstormed without blocking (the nominal group condition and Condition 3). Furthermore, a planned comparison between the three blocking versus the two nonblocking conditions accounted for more than 90% of the variance due to experimental conditions. In contrast, being exposed to the ideas presented by the other participants (Condition 2) did not result in a significant reduction of productivity over and above the reduction due to mere blocking.

These findings support the assumption that blocking is a major cause of the productivity loss in brainstorming groups. Further support for the importance of blocking comes from studies that demonstrate that productivity losses can be eliminated by having ideas shared through procedures that avoid blocking, such as the use of written notes (“brainwriting”; Paulus & Yang, 2000) or computers (“electronic brainstorming”; e.g., Gallupe et al., 1991). Furthermore, Gallupe et al. (1994) found that introducing blocking in electronic brainstorming (EBS) groups (e.g., by having group members take turns before typing their ideas) produces a productivity loss similar to that usually found in verbal brainstorming groups.

Besides establishing the importance of production blocking in explaining productivity loss in groups, the findings of Diehl and Stroebe (1987, Experiment 4) also allow one to rule out a few of the multitude of psychological explanations for the blocking effect. That overhearing the ideas of others (Condition 2) did not significantly reduce productivity compared to the condition of mere blocking without communication (Condition 1) is inconsistent with the explanations that participants in groups produce less because they are distracted or because they abandon ideas that no longer appear to be novel in the light of the ideas presented earlier by other participants. However, these findings do not rule out the possibility that *lack of time* for presenting ideas is responsible for the blocking effect. Because groups and individuals are allowed the same amount of time for their brainstorming session, participants in group sessions have considerably less speaking time than those in individual sessions. Having less time to present their ideas could therefore be responsible for the lower productivity of individuals who brainstorm in groups. However, Diehl and Stroebe (1991, Experiment 2) ruled out this explanation in a further experiment in which participants, who brainstormed individually for 20 min, either were allowed to report their ideas during the whole period or had their reporting time limited to 5 min. However, even when time was limited, participants could speak at any time they wanted, as long as their total speaking time (measured with a voice-controlled clock) did not exceed 5 min. The results were quite clear. As long as participants could speak at any time, restriction of speaking time did not reduce the productivity of nominal groups, which was significantly higher than that of a control group, who brainstormed in a 20-min group session. Thus, the evidence so far seems to suggest that the forced delay in presenting ideas is the major cause of the blocking effect. It further suggests that the blocking effect may be due to cognitive interference, a hypothesis that was examined in Phase 2.

2.4. Implications

Phase 1 research has shown that a major cause of the productivity loss in brainstorming groups is a problem with coordinating individual group members' contributions: group members simultaneously generate ideas but can only express them sequentially, which creates a procedural "bottle-neck." In terms of Steiner's (1972) theory of group performance, the productivity loss of brainstorming groups is therefore to a large extent (though not exclusively, see Camacho & Paulus, 1995; Paulus & Dzindolet, 1993) due to coordination losses. Motivation loss (e.g., free riding or social loafing) seems less important. Because group discussions by nature require turn-taking among group members, production blocking and associated coordination losses may be observed during all kinds of group discussions. Indeed, we have probably all experienced a situation in which

we wanted to contribute an important piece of information, but were simply unable to do so, because other members kept on talking (and usually, so it seems, about less important matters). The implication, therefore, is that production blocking is one major reason why some tasks should not be performed in groups: the sequential nature of group discussion makes groups inefficient when all members could potentially contribute to the discussion.

It is interesting to note that, despite the consistent failure of brainstorming groups to reach the level of productivity achieved by nominal groups, traditional brainstorming groups are still widely used in business organizations and advertising agencies. Entering “brainstorming” in Google (October 2009) results in more than 6 million hits, many of those advertisements for brainstorming training. Furthermore, surveys show that most people think they are much more creative when generating ideas in groups than individually (Paulus et al., 1993). This illusion of group efficacy (Nijstad et al., 2006; Stroebe et al., 1992) is so powerful that even after having participated in both individual and group brainstorming sessions as part of classroom demonstrations, participants were (erroneously) convinced that they were more productive in the group than when working individually.

Researchers have so far identified three reasons why group members are typically more satisfied with their performance than individual brainstormers. One is memory confusion: Group members have difficulty distinguishing between ideas they have generated themselves and ideas generated by other group members and, as a result, overestimate their own contribution. In support of this assumption, Stroebe et al. (1992) found that members of four-person brainstorming groups claimed that no less than 60% of the ideas generated in a group session had also occurred to them. They were also less accurate than individual brainstormers in identifying ideas that had been suggested by them. A second potential reason is the unavailability of comparison persons in the individual brainstorming sessions (Paulus et al., 1993). Due to the inability to compare their own performance to that of other individuals, individual brainstormers are uncertain and anxious about their own performance. In group sessions, individuals typically find that their performance is similar to that of other group members and are therefore satisfied with their own performance. In support of this explanation, Paulus et al. (1993) found that participants who worked individually but were provided with performance information of a fellow participant rated their performance more favorably than participants who did not receive this information. A third potential reason for the greater satisfaction of individuals who brainstorm in groups rather than individually is that the former are likely to have fewer cognitive failure experiences than the latter. Cognitive failures are experienced when participants in brainstorming sessions are unsuccessful in their search for new ideas. There are two reasons why this is less likely to happen in group than individual brainstorming

sessions. First, in group sessions, individuals share the work with others and therefore do not need to contribute as many ideas. Second, each time they have contributed an idea, they can relax and listen to other group members, which will allow them to recover. Both these factors lessen the risk of cognitive failure experiences. In support of this assumption, Nijstad et al. (2006) demonstrated that participants reported more failure experiences after individual than group sessions and that statistical control of these failure experiences eliminated the difference in satisfaction that was otherwise observed between group versus individual sessions.

3. PHASE 2: DEVELOPING AND TESTING A COGNITIVE MODEL OF PERFORMANCE IN IDEA GENERATING GROUPS

3.1. SIAM: A theory of idea generation

Although Phase 1 research had clearly identified production blocking as a major cause of the productivity loss of brainstorming groups, it was less clear why blocking had these detrimental effects. Because it seemed most plausible that some type of cognitive interference was responsible for the blocking effect, it became important to have a theory about the cognitive processes underlying idea generation. For this reason, SIAM was developed as a theory of the way individuals generate ideas (Nijstad, 2000; Nijstad & Stroebe, 2006; Nijstad et al., 2002, 2003). SIAM is an extension of Raaijmakers and Shiffrin's (1981) SAM model of memory retrieval. Because new ideas cannot be directly retrieved from memory, idea generation differs from the retrieval of learned material, which is the phenomenon SAM was developed to explain. However, because even new ideas must be based on existing knowledge (Amabile, 1983), idea generation necessarily involves retrieval processes. Like SAM, SIAM assumes that there are two memory systems: a limited capacity working memory (WM), in which conscious operations are performed, and an unlimited capacity long-term memory (LTM) in which all previously acquired knowledge is stored. The LTM consists of elements that are richly interconnected via a network of associations (associative memory). Thus, SIAM can be considered an extension of the SAM model.

Like SAM, SIAM assumes that LTM is partitioned into *images* (no visual or spatial representation is implied), which form the units of LTM. These images consist of semantically related elements. For example, the image "university" has features such as "has students," "has professors," and "has lecture halls." Images have fuzzy boundaries and there can be a great deal of overlap between different images. For example, the image "university" has a great deal of overlap with the image "high school." However, the

connections between features within an image are assumed to be closer than those between different images.

According to SIAM, brainstorming is a repeated search for ideas in associative memory. The generation of ideas is a two-stage process, consisting of a stage of knowledge activation followed by a stage of idea generation. Because knowledge must be relevant to the topic at hand, the initial activation of knowledge is a controlled process. Like the SAM model, SIAM assumes that a search cue is assembled in WM, which is used to probe LTM. This search cue contains elements of the brainstorming problem and other elements, such as previously generated ideas. A cue-based search of LTM results in the activation of an image. To activate knowledge means that the knowledge is temporarily placed in WM. Which image is activated is probabilistic, and depends on the strength with which the elements of the search cues are associated with the image's features. It is assumed that only one image can be activated in WM at any given time.

When an image has been activated, it can be used in Stage 2 to generate ideas by combining knowledge, forming new associations, or applying knowledge to a new domain (Mednick, 1962). This results in the generation of one or more ideas, which can subsequently be expressed. Further ideas can be added to the search cue to activate new images in LTM. Because semantically related images are assumed to have strong mutual ties, successively activated images will often be semantically related. This results in a "train of thought," a rapid accumulation of semantically related ideas. When a train of thought no longer leads to new ideas, a new search cue must be assembled, a process which takes some time. The new cue is then used to probe memory and results in the activation of new images and the generation of additional ideas. This process continues until the session is terminated or brainstorming ceases for lack of new ideas.

An example may help to illustrate this process of idea generation. Suppose that you have been asked by a governmental agency to develop an intervention to reduce smoking levels in your country. You may first think of the usual interventions: a health education campaign, informing people that smoking kills, that smokers have bad breath, and that smoking is no longer cool. However, you are then likely to remember that this type of campaign has not been very successful. One reason is that people are addicted and often unable to stop. You may therefore start to consider strategies to help smokers quit (e.g., support groups, behavioral therapy, etc.). Another reason for the lack of success of health education campaigns could be that cigarette advertising has still not been banned totally; you may then suggest forbidding any advertising for smoking, even on racing cars. Continuing to think about legal measures as a way to reduce smoking, you may then consider forbidding smoking in restaurants and offices, increasing the legal age limit at which smoking is allowed, and forbidding sale of cigarettes through vending machines. As this example illustrates, brainstorming sessions can be seen as

a series of successive trains of thought dealing with particular semantic domains related to the problem (e.g., health education, legal measures, taxation); ideas are likely to be generated in semantically related clusters.

3.2. Measures of semantic and temporal clustering

How could this model be tested? Clearly, the traditional measure of idea quantity is not suited for this task. However, it is possible to gain insight into the nature of the brainstorming process by studying the *content* of generated ideas. SIAM assumes that one image can be used to produce different ideas and that these ideas should be semantically more closely related than ideas developed from different images. Although it is not possible to observe the activation of images directly, category systems for ideas have been developed, which make it possible to code ideas into semantic categories (e.g., Diehl, 1991). It seems reasonable to assume that when two successive ideas are coded into the same category (so-called *category repetitions*), they are generated from the same image.

The category systems used in our research have been developed by Diehl (1991) and are based on a goals-by-means matrix framework. Diehl (1991) developed categories by breaking superordinate goals down into various subgoals, which he then crossed with a number of means to reach these goals. For example, the goal of preserving the environment can be broken down into 10 subgoals (e.g., reduce the production of waste, reduce air pollution, reduce energy consumption, increase use of “green energy”), which in turn can be crossed with five means (e.g., consumption, production, organization, action), resulting in 50 categories. With this kind of categorization, it can be established whether an idea is a category repetition (and is thus likely to be generated from the same image) or reflects a category change. One can also compute other important measures, such as cluster length (average number of successive ideas within a category), category fluency (average number of ideas per category), and idea diversity (number of categories used), as illustrated by Fig. 4.2. In addition to cluster length, one can also compute the adjusted ratio of clustering (ARC; Roenker et al., 1971). The ARC is a measure of the degree to which consecutive ideas fall into the same category, corrected for chance. It is mathematically independent of the number of ideas generated, the number of categories surveyed, and the average number of ideas within each category.²

² The formula to compute the ARC is: $ARC = (R - E(R)) / (\max R - E(R))$ where R is the number of observed category repetitions, $E(R)$ is the expected number of category repetitions according to chance, and $\max R$ is the maximum number of category repetitions. $\max R$ is equal to $N - k$, where k is the number of categories surveyed by a participant, and N is the total number of ideas generated.

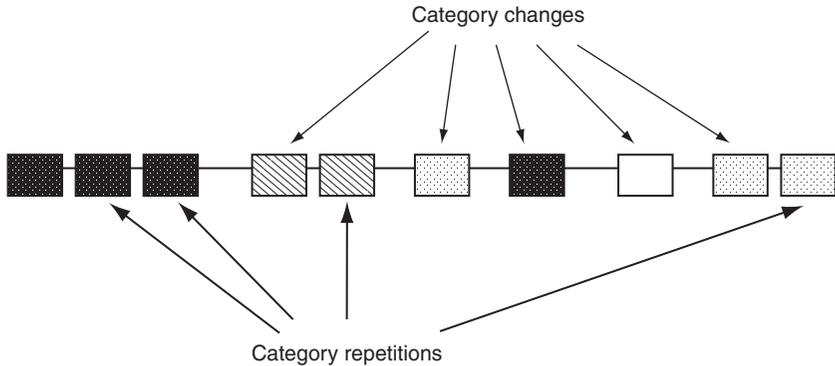


Figure 4.2 Measures of brainstorming performance used in Phase 2 research (from Nijstad & Stroebe, 2006). *Note:* In this hypothetical sequence of ideas, each box represents an idea, whereas each different pattern represents a different category. In this example, 10 ideas have been generated. This is the measure of productivity. Four of these ideas represent category repetitions, because they are coded in the same category as the previous idea. There are six semantic clusters, separated from each other by category changes (an idea is coded in a different category than the previous one). To illustrate our finding that category repetitions are faster than changes, we used shorter distances between boxes for category repetitions than for category changes. The average cluster length in this case is 10 ideas divided by six clusters = 1.67. In total, four different categories have been used in the example, and this is our measure of idea diversity (number of categories sampled at least once). Dividing the number of ideas by the number of categories results in within-category fluency (the average number of ideas per category, 2.5 in this case). Finally, the adjusted ratio of clustering (ARC) can be computed (Roenker et al., 1971), and the ARC is 0.50 in this case.

Because SIAM is a theory of the cognitive processes involved in individual idea generation, we will below first present tests of its predictions regarding individual brainstorming (Nijstad & Stroebe, 2006); then, we will address the implications of SIAM for group idea generation.

3.3. Individual idea generation

According to SIAM, successively generated ideas are likely to be derived from the same image and should therefore be semantically related. Thus, one should expect to find semantic clustering in idea generation: Successive ideas should be relatively likely to belong to the same category (i.e., category repetition), rather than to different categories. Furthermore, following a train of thought and generating ideas within a semantic category should take less time than changing categories, because category changes are likely to involve the development of a new search cue. Finally, because category changes are slower than category repetitions, it should be more time-efficient to have high levels of clustering (i.e., many category

repetitions). Thus, the amount of clustering should be positively related to the quantity of ideas produced: the more people generate subsequent ideas within semantic categories, the less time will they need to generate these ideas, and the higher should be their productivity within a given period of time.

These hypotheses were tested using the data from the control groups of four different experiments (Nijstad et al., 2002, 2003). As in all experiments conducted to test predictions from SIAM, participants worked at a computer terminal and entered their ideas directly into the computer. They were given 20 min and asked to produce as many ideas as possible on topics such as the preservation of the environment or health improvement. As one can see from Table 4.2, the results of all four studies are similar and supportive of the hypotheses. Firstly, in all studies the ARC was positive and significantly different from zero, which provides support for the SIAM prediction of semantic clustering. Secondly, response latencies for category changes were greater than for category repetitions. Thirdly, the ARC was significantly positively correlated with the number of ideas produced. Although all predictions were supported by significant results in all four experiments, a meta-analytic test of each prediction combining the results of all four studies was also conducted. With effect sizes of $d = 0.80$ or greater considered large (e.g., Rosenthal, 1995), all the effect sizes were large. Also, for each effect, the homogeneity statistic Q_w was computed. With none of the Q_w statistics significant, the four sets of findings can be considered independent replications of the same effect. Thus, these findings provide strong support for predictions derived from SIAM about idea generation in individual sessions.

3.4. Group idea generation: Production blocking and cognitive interference

Because social norms dictate that group members take turns in presenting their ideas, production blocking is an inevitable consequence of verbal communication in groups. When group members wait for their turn, delays arise between the generation and articulation of ideas. These delays due to production blocking can interfere with idea generation in two ways, which are related to the two stages of idea generation: They can disrupt the activation of images, or they can interrupt the continuation of a train of thought (Fig. 4.3).

If a participant has generated an idea but cannot express it immediately, because somebody else is talking, the idea needs to be stored in WM. The longer the idea needs to be kept in WM, the greater the chance that it will be forgotten and that the image from which it was derived will be deactivated. Once an idea has been forgotten and an image deactivated, a new search cue has to be constructed. SIAM therefore predicts that the longer

Table 4.2 Data related to clustering in individual idea generation (control conditions only) (adapted from Nijstad & Stroebe, 2006)

Measure/parameter	Study				Effect size <i>d</i> (95% confidence interval)
	Nijstad et al., 2003, Exp. 1 (<i>N</i> = 10)	Nijstad et al., 2003, Exp. 2 (<i>N</i> = 20)	Nijstad et al., 2003, Exp. 3 (<i>N</i> = 17)	Nijstad et al., 2002 (<i>N</i> = 14)	
ARC: <i>M</i> (SD)	0.41 (0.18)	0.20 (0.15)	0.29 (0.10)	0.30 (0.14)	–
ARC > 0	<i>t</i> = 7.13, <i>p</i> < 0.001	<i>t</i> = 6.25, <i>p</i> < 0.001	<i>t</i> = 11.29, <i>p</i> < 0.001	<i>t</i> = 7.69, <i>p</i> < 0.001	1.87 (1.44, 2.30)
Response latencies of Category changes (s)	26.13 (7.66)	25.37 (14.86)	30.02 (8.20)	41.53 (12.06)	–
Response latencies of Category repetitions (s)	19.89 (6.38)	19.52 (12.54)	21.64 (9.56)	29.33 (8.78)	–
Difference	<i>t</i> = 4.48, <i>p</i> < 0.01	<i>t</i> = 2.09, <i>p</i> = 0.05	<i>t</i> = 4.20, <i>p</i> = 0.001	<i>t</i> = 5.22, <i>p</i> < 0.001	0.91 (0.53, 1.28)
Correlation ARC— productivity	<i>r</i> = 0.59, <i>p</i> = 0.07	<i>r</i> = 0.49, <i>p</i> = 0.03	<i>r</i> = 0.71, <i>p</i> = 0.001	<i>r</i> = 0.41, <i>p</i> = 0.15	1.26 (0.87, 1.65)

ARC, adjusted ratio of clustering; *d*, Cohen's *d* for effect sizes.

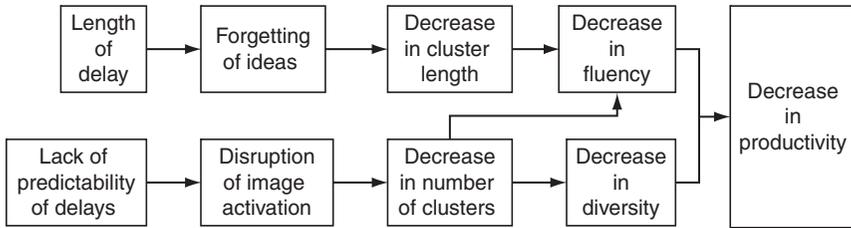


Figure 4.3 The two-stage theory of production blocking (from Nijstad et al., 2003).

the delays, the greater the probability that a train of thought is interrupted. This should result in shorter clusters and also in a decrease in the number of ideas produced per category (category fluency). As a consequence, there should also be a decrease in overall productivity (Fig. 4.3, top panel).

The bottom panel of Fig. 4.3 depicts the second way in which delays can interfere with idea generation. The activation of images is a controlled process which requires cognitive resources (i.e., WM capacity). The greater the cognitive load due to other cognitive tasks, the more the individual's ability to activate images will be impaired. One major cause of cognitive load is the need for group members to monitor the current speaker in order to be ready to present their own ideas as soon as that person stops talking. Because there are usually no fixed speaking terms in brainstorming groups, it is typically unpredictable when one will have the opportunity to express one's ideas. In addition, the length of speaking terms can vary considerably (some group members take more time expressing their ideas than others), which introduces another source of unpredictability. Thus, when delays are unpredictable and hence increase cognitive load, the individual's ability to activate images will be impaired. Thus, whereas delay length results in *shorter* trains of thought due to forgetting and image deactivation, delay unpredictability will result in *fewer* trains of thought, because fewer images are activated. This can be observed in a reduction of the number of semantic clusters and consequently also in a reduction in the number of categories that are being surveyed during idea generation (i.e., a decrease in diversity). Moreover, when people's ability to activate images is impaired, this can also mean that they are less likely to return to a previously accessed category (i.e., a decrease in fluency).

Nijstad et al. (2003) tested these predictions in experiments in which participants worked individually at computer workstations. Whereas participants in the control condition could enter their ideas whenever they wanted, participants in the experimental conditions often had to wait before they could enter an idea. The introduction of waiting periods was justified with the argument that these were needed to simulate the situation of interactive brainstorming groups (which in a sense was true, of course).

This experimental situation enabled us to manipulate the duration and predictability of the waiting periods. In one experiment (Nijstad et al., 2003, Experiment 1), participants generated ideas about what people can do to help preserve the environment, a topic that was quite familiar to the Dutch university students who participated. Participants in the experimental conditions were blocked (i.e., had to wait) each time they wanted to enter an idea. Depending on conditions, the duration of the waiting time varied between 1 and 7 s. As predicted, longer waiting periods resulted in shorter clusters of semantically related ideas, lower clustering (ARC), a reduction of the number of ideas per category (within-category fluency), and a decrease in overall productivity (i.e., quantity of ideas produced). Moreover, the effects of delay length on within-category fluency and overall productivity were fully mediated by cluster length, which constituted further support for SIAM. However, these predictable delays had no effect on the number of clusters, nor on diversity (i.e., number of categories surveyed), presumably because little cognitive capacity was required to monitor delays (after all, participants soon found out they had to wait every time they wanted to enter an idea).

In another experiment (Nijstad et al., 2003, Experiment 3), participants again brainstormed on ways to help preserve the environment. The researchers manipulated the predictability of delays. In the condition with high predictability, participants had to wait 7 s each time they wanted to enter an idea. In the condition with unpredictable delays, 60 delay periods were randomly distributed over the 20 min session. Furthermore, the duration of delays varied between 2 and 12 s (average duration = 7 s). These participants were sometimes blocked several times before they could enter an idea, but sometimes they could also enter several ideas before they were blocked. This made the delays truly unpredictable. In the control condition, participants could enter ideas any time they wanted.

Results in the predictable delay condition replicated the findings of Experiment 1. Thus, predictable delays reduced cluster length, and this in turn reduced productivity (see Table 4.3). As in Experiment 1, predictable delays had no effect on number of clusters. In contrast, when delays were unpredictable, the number of clusters decreased, whereas cluster length was not affected. Moreover, the reduction in the number of clusters was associated with the predicted reduction in the average number of ideas per category (within-category fluency) and with a reduction in productivity. As in Experiment 1, a mediation analysis was performed, which replicated the earlier findings that cluster length mediated the effect of delays for the condition with predictable delays. In contrast, a mediation analysis performed on the data of the unpredictable delay condition suggested number of clusters as mediator: When the number of clusters was statistically controlled for, the effect of unpredictable delays on productivity became insignificant.

Table 4.3 Productivity, cluster length, number of clusters, diversity, within-category fluency, and clustering (ARC) as a function of delays (adapted from Nijstad et al., 2003, Exp. 3)

Dependent variable	Delay condition			F-value ANOVA
	Control	Predictable delays	Unpredictable delays	
Productivity	45.78 ^a (11.95)	35.76 ^b (10.46)	35.67 ^b (9.82)	6.67**
Cluster length	1.36 ^a (0.12)	1.22 ^b (0.12)	1.41 ^a (.32)	2.86*
Number of clusters	33.26 ^a (6.84)	29.32 ^{ab} (8.09)	26.22 ^b (8.12)	5.52**
Diversity	15.24 ^a (3.26)	16.12 ^a (3.90)	16.24 ^a (3.95)	0.18
Within-cat. fluency	3.01 ^a (3.03)	2.20 ^b (2.21)	2.21 ^b (2.18)	16.85***
ARC	0.29 ^{ab} (0.10)	0.22 ^b (0.15)	0.36 ^a (.23)	2.93*

Note. Standard deviations are in parentheses. Different superscripts (a, b) indicate a significant difference on a *post hoc* test (LSD). *, $p < 0.10$; **, $p < 0.01$; ***, $p < 0.001$.

In sum, the findings of these two experiments support the SIAM predictions that production blocking interferes with idea generation at both stages of the process (image activation and actual idea generation) and that two different processes explain the effect of delays: The *duration* of delays affects the *length* of clusters, whereas the (un)predictability of delays influences the *number* of clusters. Obviously, in interactive brainstorming groups, both effects should occur concurrently, because the amount of time taken to express ideas differs both between and within speakers. These blocking effects should also be stronger at the beginning of a brainstorming session, when group members are likely to think of more ideas than toward the end of a session.

3.5. Cognitive stimulation and productivity

Because production blocking is an inevitable consequence of verbal communication in idea generating groups and has powerful negative effects on productivity, the identification of blocking as the main reason for the productivity loss in brainstorming groups led to a reassessment of the cognitive stimulation hypothesis. It seemed possible that exchanging ideas could be stimulating, as Osborn (1957) had originally suggested, but that in interactive groups this stimulation effect was overshadowed by the powerful impact of production blocking. SIAM actually predicts such stimulation effects: exposure to other people's ideas should shorten the time needed to assemble LTM search cues for relevant knowledge (because the other person's idea can serve

as a search cue). Depending on the semantic content of the stimulus ideas, two types of positive effects are possible. Firstly, exposure to other people's ideas can activate knowledge that—due to low accessibility—might otherwise not have been activated. This is particularly likely when the stimulus ideas are semantically diverse (heterogeneous stimulation). However, by increasing category diversity, heterogeneous stimulation could result in a decrease in processing depth (i.e., it may result in a lower number of ideas per category), because it could trigger premature category changes. Thus, heterogeneous stimulation will increase overall productivity *only* if the increase in productivity due to the increase in the number of categories accessed outweighs the potential decrease due to premature category changes. Secondly, exposure to semantically homogeneous stimulus ideas will result in greater processing depth (people will generate more ideas within a particular category), and thus the production of a greater number of ideas within the categories that are being stimulated. On the negative side, this type of stimulation could result in a decrease in diversity. However, as long as the stimulated categories are sufficiently rich not to be exhausted under normal conditions, homogeneous stimulation should result in productivity gains.

Research on stimulation effects has commonly used procedures that allow for an exchange of ideas without production blocking. The best known of these is EBS, where group members work on computers which are connected via a computer network. This makes it possible for group members to type in their ideas whenever they want to, but at the same time enables them to look at the ideas of other group members displayed on their monitors. Thus, group members have the opportunity to be stimulated by each other's ideas, but do not have to wait until they can enter their own ideas. Another procedure is "brainwriting," where group members write their ideas on cards and exchange these cards during the brainstorming session. This research reported somewhat conflicting results, which is hardly surprising in view of the opposing processes triggered by exposure to ideas of others.

With regard to EBS, [Dennis and Valacich \(1993\)](#) and [Valacich et al. \(1994\)](#) found that relatively large EBS groups ($n > 9$) outperformed equivalent nominal groups. It is unclear why smaller EBS groups did not produce stimulation effects. One reason could be that, in smaller groups, the negative effects of heterogeneous stimulation (i.e., reduction in processing depth) outweighed the positive effects of diversity. This may not have been the fact for large brainstorming groups, because these are likely to produce ideas from a much wider range of categories. Another potential reason, which is suggested by research of [Dugosh et al. \(2000\)](#), may have been that participants in smaller EBS groups for some reason paid less attention to the stimulus ideas displayed on their screen. Dugosh et al. found that even small EBS groups (four persons) outperformed nominal groups, but only if group members had been explicitly asked to pay close attention to the ideas produced by other members. Without such instructions, the productivity of EBS groups was not

significantly different from that of nominal groups. Lack of attention to the ideas of others may also have been the reason why a study by Ziegler et al. (2000) failed to find a difference between two- and four-person EBS and nominal groups. Ziegler et al. (2000) reported that their EBS groups produced as many redundant ideas (i.e., ideas already mentioned by other group members) as their nominal groups. If members of EBS groups had paid close attention to the ideas of other members, they should have been less likely than members of the nominal groups to suggest the same ideas later themselves.

Further evidence of stimulation effects comes from the study by Dugosh et al. (2000) mentioned earlier. These researchers had participants listen to a tape recording of somebody generating ideas on a particular problem; after this, participants were asked to brainstorm on the same problem. Compared to individuals who had not listened to such a recording, participants who had listened produced significantly more ideas, but only if they had been explicitly instructed to pay close attention to the recorded ideas. Similar stimulation effects were reported by Paulus and Yang (2000) in a study that used a brain-writing procedure. These authors found that participants who could share ideas through written notes outperformed nominal groups without sharing.

Although the findings reported so far provide compelling evidence for stimulation effects, they lack the specific information needed to assess the processes that, according to SIAM, should mediate these stimulation effects. To test SIAM's predictions regarding cognitive stimulation, one needs to know (a) whether the set of stimulus ideas is homogeneous or heterogeneous, and (b) whether stimulation increased category diversity or within-category fluency. Nijstad et al. (2002) therefore conducted a study that used the same computer procedure as the blocking studies: Participants were seated at a computer terminal and were asked to type in their ideas. In the control condition, no stimulation was offered. In the experimental conditions, an idea from the pool of ideas produced by other participants was displayed on participants' monitor each time they had typed in an idea. Under conditions of *heterogeneous* stimulation, these ideas came from a wide range of different categories. Under conditions of *homogeneous* stimulation, they came from a much smaller number of categories. Consistent with predictions, both types of stimulation resulted in an increase in overall productivity (Table 4.4). Furthermore, as predicted, heterogeneous stimulation increased category diversity, but not within-category fluency; in contrast, homogeneous stimulation increased the number of ideas produced per category (within-category fluency), but not the number of categories (category diversity).

A further prediction that can be derived from SIAM refers to response latencies. Earlier, we described results that showed that response latencies of category repetitions are shorter than those of category changes. The reason, we suggested, is that before a category change, a search cue has to be

Table 4.4 Productivity, diversity, within-category fluency, and response latencies by condition (adapted from Nijstad et al., 2002)

Measure	Condition			F-value ANOVA
	No stimulation control (N = 15)	Homogeneous stimulation (N = 24)	Heterogeneous stimulation (N = 24)	
Productivity	32.40 ^a (10.54)	39.83 ^b (10.06)	40.29 ^b (10.54)	3.14**
Diversity	14.27 ^a (2.84)	13.04 ^a (2.44)	17.67 ^b (3.82)	13.85***
Within -category fluency	2.24 ^a (0.42)	3.08 ^b (0.63)	2.28 ^a (0.35)	20.67***
Response latency category change (s)	41.53 ^a (12.06)	23.86 ^b (3.94)	24.94 ^b (6.70)	27.49***
Response latency category repetition (s)	29.33 ^a (8.78)	22.78 ^a (6.14)	26.21 ^a (9.85)	2.69*

Note. Standard deviations are in parentheses. Response latencies are in s. Different superscripts (a, b) indicate significant differences on a LSD *post hoc* test. *, $p < 0.10$; **, $p < 0.05$; ***, $p < 0.001$.

developed to probe LTM, and this process takes some time. However, in the stimulation conditions of the Nijstad et al. (2002) study, elements of a search cue were readily available from the stimulus ideas, and the availability of stimulus ideas should thus especially reduce response latencies of category changes. This is indeed what was found (Table 4.4). In the control condition without stimulation, category changes were slower than category repetitions. However, this was not the case in the two stimulation conditions, where category changes were as fast as category repetitions and faster than category changes in the control condition. Thus, stimulation was effective because it reduced response latencies of category repetitions, presumably because stimulation ideas could be readily used to probe LTM.

An unpublished study by Diehl et al. (2002) provides further support for the effect of heterogeneous stimulation. In this experiment, participants were placed at a computer terminal and had to produce ideas about how to improve their own health. Participants in the control condition simply entered ideas, but individuals in the stimulation conditions could press any of 11 stimulation keys on their keyboard whenever they felt that they had run out of ideas. Depending on the experimental condition, pressing the stimulation key either

generated one of the 11 health subgoals of Diehl's (1991) category system (e.g., avoid weight problem; maintain or improve physical fitness) or two specific ideas relevant for this subgoal. Stimulation with specific ideas or with categories increased category diversity as well as overall productivity. However, when individuals were stimulated with both the category labels and a set of specific ideas at the same time, the stimulation through specific ideas failed to have an impact. This suggests that even the stimulating effect of specific ideas was mediated by the activation of new categories. This finding is consistent with SIAM, because category labels and specific ideas falling in a category should have similar effects: Provide access to categories of ideas that normally are less accessible. Because specific ideas prime the same knowledge as do category labels, having both has no additional advantage.

3.6. Implications

The Phase 2 research is consistent with the conceptualization of groups as information processors (De Dreu et al., 2008b; Hinsz et al., 1997). In this view, groups need to process information (much like individuals do), and this requires the encoding, storage, and retrieval of information (at the individual level) as well as the communication of information among group members (at the group level). The Phase 2 research shows that communication (group-level processing) can interfere with individual-level cognitive processes through production blocking, but can also stimulate these processes. Applying Raaijmakers and Shiffrin's (1981) SAM model to idea generation has resulted in testable predictions about how communication affects the mental processes of group members. It therefore seems fruitful to use theories from cognitive psychology and apply them to group research.

We noted that idea generation differs from retrieval, because ideas need to be produced through, for instance, novel combinations of existing knowledge. It is, however, interesting to note that several phenomena that can be observed in brainstorming groups can also be found in groups that work on a free recall task (i.e., a task that only involves retrieval). For example, Weldon and Bellinger (1997) and Basden et al. (1997) have found that interactive groups perform more poorly on recall tasks than nominal groups. Moreover, Basden et al. found that the level of semantic clustering in group recall was much lower than in individual recall and argued that this suggests that communication interfered with individual-level retrieval processes. This suggests that the interference and stimulation effects found during Phase 2 research may generalize to other (cognitive) tasks that are performed in group settings. One such other task is group decision making. The quality of group decision making depends in part on an adequate exchange of information (e.g., Stasser & Titus, 1985), which in turn requires that group members recall decision-relevant information during group discussion. The likelihood that a group member recalls certain

information probably depends on the information that is previously shared by another group member. These microlevel processes may be important for decision quality, a possibility that deserves further study.

4. PHASE 3: BRAINSTORMING AND CREATIVITY

4.1. Cognitive stimulation and creativity

As mentioned in the introduction, brainstorming was developed as a method to increase group creativity. Creativity is usually defined as the generation of ideas, insights, and problem solutions that are both original (novel) and appropriate (relevant, feasible) (e.g., [Amabile, 1983](#); [Sternberg & Lubart, 1999](#)). However, brainstorming research in Phases 1 and 2 often did not focus on creativity, but rather focused on quantitative measures of performance (and the content of ideas in Phase 2). Indeed, accepting [Osborn's \(1953, 1957, 1963\)](#) credo that quantity breeds quality, the research reported so far was conducted with the implicit assumption that any stimulation effects resulting in an increase in idea quantity would also increase idea quality. The high correlation between quantity and quality of ideas typically found in studies that assessed both measures tends to support this assumption (e.g., [Diehl & Stroebe, 1987](#); [Parnes & Meadow, 1959](#)). The prediction that quantity and quality are closely related is based on the assumption that the production of creative ideas is a random process and that each idea that is generated has, on the whole, the same probability of being a good or a bad idea. Therefore, any increase in the number of ideas increases both the number of good and the number of bad ideas, while the ratio of the two remains more or less constant. As a result, the number of good ideas is highly correlated with quantity, but average quality is not ([Diehl & Stroebe, 1987](#)).

As [Rietzschel et al. \(2007\)](#) argued, the assumption that the generation of creative ideas is a simple random process is psychologically neither plausible nor fruitful. To come to a valid explanation of idea generation and of the quantity–quality relation, cognitive processes underlying idea generation need to be taken into account. [Rietzschel et al. \(2007\)](#) therefore integrated the creative cognition approach of [Finke et al. \(1992\)](#) with assumptions of SIAM to arrive at a theory of creative idea generation. According to SIAM, the relevant knowledge that is accessible at a given moment will be used for the generation of ideas. Thus, the knowledge which is most accessible and therefore most easily retrieved is most likely to be used in idea generation. Unfortunately, knowledge accessibility is inevitably linked to habitual thinking, because frequent use of particular cognitive structures enhances the chronic accessibility of these structures (e.g., [Aarts & Dijksterhuis, 2000](#)). Consistent with this assumption, [Ward \(1994\)](#) and [Ward et al.](#)

(2002) found a strong tendency among their participants to rely on highly accessible properties and exemplars when generating new instances of specific categories such as animals or tools.

To explain these findings, Ward (1994) formulated the *path-of-least-resistance* model. According to this model, people tend to generate instances or ideas with the least cognitive effort possible. Along similar lines, Stein (1975) and Perkins (1981) argued that people usually start out by generating conventional ideas, because they rely on knowledge that is highly accessible. Only after these ideas have been verbalized, and thus “removed” from the pool of potential ideas, will more original ideas be generated (provided that individuals are motivated to keep on searching). This suggests that to enhance creativity, one has to induce people to leave the path of least resistance. As discussed earlier, there are two strategies to achieve this: One can either stimulate category diversity to increase the breadth of idea generation or increase the depth of idea generation by stimulation with ideas from a homogeneous set of categories. As Nijstad et al. (2002) demonstrated, both strategies can increase productivity. Unfortunately, however, Nijstad et al. (2002) only focused on the impact of these manipulations on category fluency and category diversity and failed to assess the impact of their manipulations on creativity.

Rietzschel et al. (2007) therefore designed a study to assess the impact of “deep exploration” of a brainstorming problem on the creativity of the ideas that are being produced. Instead of using the manipulation of Nijstad et al. (2002), Rietzschel et al. (2007) developed a priming procedure that increased the accessibility of particular knowledge domains without the need to actually expose participants to other people’s ideas. The brainstorming problem was the issue of what people could do to maintain or improve their health. Before the brainstorming session, participants in the priming condition were induced to think actively about one of the subtopics of the health problem (nutrition, hygiene, exercise). This was achieved by presenting them with four open-ended questions which they had to answer in writing (e.g., How much time and attention do you usually devote to healthy nutrition [hygiene, exercise]? How important do you think it is for people to devote time and energy to healthy nutrition [hygiene, exercise]?). In addition, two control conditions were used. In one of these, participants were asked the open-ended questions with regard to a health-irrelevant topic (politics) in order to assess potential unspecific effects of the priming procedure. In a second control condition, participants brainstormed without having gone through a priming procedure at all.

Rietzschel et al. (2007) expected that the priming manipulation would induce participants to engage in deeper exploration of the primed subtopic. As a result, participants should produce a higher percentage of ideas within the primed subtopic than participants who had not been primed; they

should also generate more *original* ideas within that subtopic and generate a higher percentage of *good* ideas (ideas that are highly original *and* highly feasible). As we can see from Table 4.5, results supported these predictions: Participants in each of the relevant priming conditions generated significantly more ideas, significantly more original ideas, and significantly more high-quality ideas than did participants in the two control conditions (irrelevant priming [politics]; no priming). For example, participants with nutrition priming generated a higher percentage of nutrition ideas than participants with irrelevant (politics) priming or no priming. These ideas were also more original than those in the irrelevant priming or the no priming conditions. Finally, participants with nutrition priming also generated a higher percentage of high-quality ideas on this topic than participants with irrelevant priming and participants with no priming. The same pattern was observed for the two other (relevant) priming conditions.

These results show that the priming manipulation was successful. Thus, inducing participants to explore a particular idea domain in greater depth increased both the quantity and the quality of the ideas produced in this domain, presumably through activation of the relevant knowledge structures. It should be noted, though, that these stimulation effects were limited to the domains that were primed. In none of the priming conditions was there an increase in the overall quantity or quality of ideas produced, because the increase in the proportion of ideas generated in the primed category was accompanied by a decrease in the percentage of ideas generated in the categories that were not primed (Table 4.5). Importantly, the increase in originality of the ideas generated as a result of priming was not associated with a decrease in feasibility, even though originality and feasibility were strongly negatively correlated ($r = -0.71$). Because good ideas should not only be original but also feasible, the fact that the priming manipulation increased originality without affecting feasibility increases the practical relevance of this study. Examples of ideas that were at least moderately original and feasible are: “Changing the layout of supermarkets so that people are more likely to see healthy products than unhealthy products,” and “adding vitamins and important minerals to beer, so that people who consume unhealthy products still get some valuable nutrients.”

As Nijstad et al. (2002) had demonstrated, the degree to which people engage in deep exploration of domain knowledge can be affected by exposure to the ideas of other group members. Rietzschel et al. (2007, Experiment 2) therefore conducted a second study which examined whether priming the domain knowledge of one group member could affect the performance of other group members in interactive brainstorming groups. In this study, the performance of two-person nominal groups was compared to two-person interactive brainstorming groups. Rietzschel et al. again used the health problem and created two experimental and one control condition: In the experimental condition with homogeneous

Table 4.5 Productivity and idea quality across and within semantic categories (adapted from [Rietzschel et al., 2007](#))

Measure	Priming				
	Nutrition	Hygiene	Exercise	Politics	No priming
Overall productivity	16.29 (8.50)	16.06 (6.51)	18.88 (13.67)	16.85 (7.73)	16.71 (7.57)
Percentage of nutrition ideas	32.08 (15.83)	16.64 (9.18)	18.43 (9.37)	21.51 (11.85)	17.77 (9.03)
Percentage of hygiene ideas	1.91 (4.40)	10.98 (15.07)	0.35 (1.43)	1.99 (3.24)	2.32 (5.31)
Percentage of exercise ideas	19.92 (9.41)	10.94 (9.12)	21.67 (14.91)	17.03 (11.94)	14.32 (7.97)
Overall originality of ideas ^a	1.65 (0.32)	1.70 (0.27)	1.78 (0.27)	1.79 (0.34)	1.68 (0.21)
Originality of nutrition ideas ($N = 91$) ^a	1.44 (0.54)	1.11 (0.22)	1.26 (0.34)	1.28 (0.47)	1.19 (0.52)
Originality of hygiene ideas ($N = 27$) ^a	2.30 (0.45)	2.07 (0.26)	1.67 (0.00)	2.08 (0.20)	2.00 (0.00)
Originality of exercise ideas ($N = 91$) ^a	1.27 (0.34)	1.13 (0.28)	1.50 (0.52)	1.35 (0.41)	1.21 (0.28)
Percentage of high-quality nutrition ideas ($N = 91$)	5.12 (12.34)	0.56 (1.65)	1.56 (3.51)	1.58 (3.12)	1.14 (3.27)
Percentage of high-quality hygiene ideas ($N = 27$)	0.29 (0.93)	1.66 (3.75)	0.00 (0.00)	0.17 (0.75)	0.45 (1.87)
Percentage of high-quality exercise ideas ($N = 91$)	1.81 (4.82)	0.00 (0.00)	4.11 (7.19)	2.36 (7.49)	0.27 (1.10)

Note. $N = 93$ participants, except where otherwise indicated. Standard deviations are in parentheses.

^a Maximum value = 5.

priming, both individuals were primed with the same subtopic (both nutrition or both hygiene). In the experimental condition with heterogeneous priming, both individuals were primed with different subtopics (one nutrition, one hygiene). Dyads in the control condition received no priming.

Predictions for nominal groups were straightforward: it was expected that homogeneous priming would result in the greatest increase in the quantity and originality of ideas produced by the nominal groups in the primed subtopic, because both dyad members should generate more ideas in that subcategory. With heterogeneous priming the impact on the primed subcategory should be weaker, because only one dyad member would have been primed in this subcategory. Finally, dyads in which neither member had been primed should produce the lowest number of ideas and the fewest good ideas within subcategories.

Matters were less clear for interactive groups. If sharing of ideas within the interactive dyads impacted on the idea generation of individual members, such exchange should *exacerbate* the impact of homogeneous priming, because it would reactivate the knowledge that was activated earlier through individual priming. In contrast, sharing of ideas should *weaken* the impact of heterogeneous priming on idea generation in the respective subcategories, due to cognitive interference: exposure to ideas from another person who had been generated with another category should interfere with one's own priming effects.

With regard to priming effects, findings were consistent with predictions. Dyads with homogeneous priming generated more ideas, more original ideas, and more good ideas in the primed subcategories than dyads with heterogeneous priming, with the latter being typically somewhat superior to dyads with no priming. Surprisingly, however, the pattern of results was the same for both nominal and interactive groups (i.e., these priming effects were not moderated by dyadic interaction). Thus, the additional stimulation through the ideas of other group members neither increased nor reduced the effect of previous knowledge activation achieved through priming. The only difference between nominal and interactive groups was the well-established finding that interactive groups were less productive than nominal groups (e.g., Diehl & Stroebe, 1987; Mullen et al., 1991).

On the whole, the findings from both studies support our interpretation of the quantity–quality relation in idea generation, namely that creative idea generation is enhanced by deep exploration of relevant domain knowledge. Manipulations that increase the quantity of ideas will probably only enhance the quality of ideas if these manipulations encourage deeper exploration of relevant domain knowledge. This suggests that the high correlation between quantity and quality usually observed in brainstorming studies is not the result of a random process, but rather of the fact that the people who produce more

ideas usually do so because they engage in deeper exploration of relevant content categories. Thus, what matters for creative behavior is that people must be induced to leave the path of least resistance. Original ideas will usually only be generated after people have suggested the more obvious ideas. The [Rietzschel et al. \(2007\)](#) studies showed that deeper exploration of knowledge within a category, brought about by priming, can serve this goal.

However, other manipulations could also increase depth of exploration. For example, [Rietzschel et al. \(2009\)](#) manipulated the scope of the brainstorming topic. Half of the participants in this study generated and selected ideas about a “broad” problem (improving education at the department of psychology); the other participants generated and selected ideas about a “narrow” problem (improving the *lectures* at the department of psychology). Thus, the narrow topic was in essence a subcategory of the broad problem. Problem scope did not affect overall productivity; thus, a narrow problem did not lead participants to generate fewer ideas. Instead, problem scope had a significant effect on idea quality: A narrow problem caused participants to delve more deeply into their domain knowledge and thereby generate ideas that were, on average, more original. This finding suggests that inducing individuals to spend more time on a brainstorming task should similarly increase the originality of ideas that are generated, because it would motivate them to delve deeper into some of the subcategories of the issue. Thus, to increase the originality of ideas to be produced in brainstorming, one should define the brainstorming problem narrowly, give participants ample time for the brainstorming session, and, finally, arrange for a preliminary session in which people are primed to think about the problem.

4.2. The selection of creative ideas

The research discussed thus far was aimed at elucidating the processes underlying idea generation and the causes of production loss in brainstorming groups. However, idea generation forms only part of the innovative process, and the availability of creative ideas is a necessary but insufficient condition for innovation (e.g., [Nijstad & De Dreu, 2002](#); [West, 2002](#)). For the actual implementation of creative ideas, the best ideas must be selected from the pool of generated ideas. For a long time, creativity researchers simply assumed that participants in idea generating sessions would also be able to identify the most creative idea. However, when this assumption was finally put to a test, it was found that people performed surprisingly poorly at selecting creative ideas ([Faure, 2004](#); [Putman & Paulus, in press](#); [Rietzschel et al., 2006](#)).

For example, [Putman and Paulus \(in press\)](#) had nominal and interactive brainstorming groups first generate ideas and then select their best ideas. Idea selection was conducted in interactive groups, with nominal groups selecting ideas from their pooled production. In line with all previous

findings, nominal groups produced more and more original ideas than interactive groups. However, although the average originality of the selected ideas was somewhat higher for groups who had generated these ideas as nominal groups than for groups who had generated ideas as interactive groups, both individuals and groups did rather poorly in identifying their best ideas (as assessed by independent raters). In a comparable study, Faure (2004) found no difference between interactive and nominal groups with regard to the quality of selected ideas. In other words, the higher productivity of nominal groups, and the resulting higher availability of original ideas, did not result in the selection of better ideas.

Rietzschel et al. (2006) also conducted a study in which nominal and interactive groups generated and selected ideas. In nominal group brainstorming sessions, participants wrote down their ideas on sheets of paper. In interactive groups, all ideas were verbalized and then written down by one of the group members. In the idea selection part of the task, participants selected and rank ordered the four best ideas. Interactive groups performed the selection as a group; members of nominal groups selected their best ideas as individuals. Again, nominal groups generated more ideas than interactive groups, and the ideas generated by the nominal groups were more original and less feasible than those generated by interactive groups. However, these differences were not present for the average originality and feasibility of the selected ideas. Replicating the pattern reported earlier by Faure (2004), the greater availability of good ideas in nominal groups did not seem to enable these individuals to select better ideas than did groups. Most strikingly, however, the average quality of selected ideas was not higher than the average quality of the generated ideas. Thus, participants' performance in selecting ideas was in fact not better than chance.

Accepted at face value, this last result could imply that the findings of three decades of brainstorming research, although of interest to small group researchers, are of no relevance for practitioners. The fact that nominal groups are more likely to come up with creative solutions than interactive groups is irrelevant, if individuals or groups are incapable of recognizing the good ideas they might have generated. Obviously, however, such a finding cannot be accepted at face value and needs to be explained.

One possible explanation lies in the question of whether the right criteria were used to assess selection effectiveness. As we mentioned earlier, practitioners as well as researchers define "good" ideas as ideas that are high in both originality and feasibility. External raters are therefore asked to evaluate ideas on those two dimensions, and it is implicitly assumed that the people who generate ideas use the same criteria when selecting their best ideas (or that they *should* at least do so). However, this need not be the case at all; it is entirely possible that these individuals attach more weight to other characteristics, which may or may not have any relation with originality and feasibility. It is conceivable, for example, that people tend to select ideas that

they generated themselves, or ideas that somehow have particular personal relevance. Alternatively, it is possible that participants in the studies described above did in fact use originality and feasibility as selection criteria, but had other views of what these dimensions entailed than the researchers and their raters. In other words, they may have been quite effective in selecting the most original and feasible ideas according to their own criteria, but, due to a disagreement between their criteria and those of external raters, performed poorly according to the criteria used by the external raters.

Rietzschel et al. (2010) conducted two studies to examine these possibilities. In one of these studies (Experiment 2), participants were presented with a set of ideas that had been generated in earlier brainstorming research. In order to gain more insight into the criteria actually used in idea selection, participants were asked to indicate how strongly they tried to select original ideas, feasible ideas, and desirable ideas (i.e., ideas which they thought should be adopted). Further, participants were asked to rate the set of presented ideas on the dimensions of originality and feasibility.

With regard to the performance on the selection task, findings replicated earlier results. Participants who had been instructed to select the “best” ideas chose ideas that were on average less original, but slightly more feasible than the average originality and feasibility of the idea set. The very high correlations between originality and feasibility ratings of participants and external raters ruled out the possibility that participants performed poorly because their perception of ideas as original or feasible differed from that of trained raters. However, the self-reports of the criteria participants used in idea selection provides some insight into the reasons for the poor performance of individuals or groups asked to select their best ideas. Ratings of whether participants had tried to select the “best” idea were positively correlated with their ratings of how strongly they had tried to select feasible ideas ($r = 0.64$) and desirable ideas ($r = 0.70$), but negatively correlated with their ratings of how strongly they had tried to select original ideas ($r = -0.40$). In contrast, participants’ tendency to select for originality was negatively correlated with their tendency to select for feasibility ($r = -0.40$) and desirability ($r = -0.48$). Thus, participants appear to consider “good” those ideas which are feasible and which they would like to be implemented. Originality does not seem to be a quality dimension that people take into account spontaneously. Rather, people seem to focus on whether they believe the idea can and should be adopted.

What can one do to improve the quality of idea selection? Because a good idea is defined as one that is both original and feasible, it would seem plausible to instruct participants to select ideas that are both original and feasible, rather than merely asking them to select good ideas (default instruction). However, use of exactly such instructions in a study where participants generated and selected ideas did not improve selection quality at

all (Rietzschel et al., 2010, Experiment 1). Participants who were instructed to select ideas which were both original and feasible did as poorly as participants who were given the default instruction to select their best ideas. Under neither of these conditions was the quality of the selected ideas significantly different from that of the generated ideas. In contrast, instructing participants to select the most *creative* ideas significantly improved selection over and above the default instructions (Rietzschel et al., 2010, Experiment 2). Compared to the default instruction, creativity instructions resulted in better selection with regard to originality, but a slightly less effective selection with regard to feasibility. However, when an aggregate measure of idea quality (the mean of originality and feasibility) was used as criterion for idea selection, only a main effect of instructions emerged. Participants with creativity instructions selected ideas of higher quality (on the combined feasibility/originality measure) than did participants with the default instruction. Two examples of high-quality ideas in these studies were: “Organize brief collective mediation session before lectures, to increase concentration,” and “All lectures should be recorded and offered online” (this is by now becoming common practice, but it was still an innovative idea when these studies were conducted). This finding strongly suggests that selection effectiveness in brainstorming groups can indeed be improved by giving the specific instruction to select creative ideas; however, it also shows that it is important to distinguish between different dimensions of idea quality.

All in all, the implicit assumption of brainstorming researchers that the participants in their studies share researchers’ conception of a good idea as one that is original and feasible is wrong. Participants do not appear to care for originality; instead, they consider an idea to be good if it is feasible and if they would like it to be implemented. Because (at least in their cognitive space) feasibility and originality are often negatively related, originality is not a quality dimension on which they spontaneously base their idea selection; if anything, high originality may count *against* ideas, rather than for them.

This raises the question whether originality is as important as creativity researchers make it out to be. After all, in many situations, it is most important that an idea works. What good are ideas that are creative, but can in no way be implemented? We believe that originality is actually quite important, for three reasons. Firstly, the results of Experiment 2 (Rietzschel et al., 2010) suggest that, on the whole, a stronger focus on originality does *not* necessarily lead to the selection of less feasible ideas. Thus, one does not seem to lose very much by way of practical value when focusing on originality. Secondly, one should keep in mind that brainstorming is specifically meant as a technique to stimulate creativity and is mainly used when conventional problem solving has failed. In such situations, originality is not an end in itself, but a necessary means to find a feasible solution outside the

realm of conventional solutions. Finally, although raters agree in finding that original ideas are often less feasible or effective, one cannot really be sure that their ratings actually predict implementation success. As the research on scientific creativity has amply demonstrated (Simonton, 1997), even experts are unable to predict which ideas will turn out to be successful in the long run. An original idea that seems quite outlandish and unfeasible may, perhaps with some modifications, turn out to be very successful after all. Indeed, if one could accurately predict the success of an idea using simple rating scales, the world would look very different today.

4.3. Implications

Because of the early emphasis of brainstorming research on a comparison between individual and group productivity, this research is often quoted to demonstrate the ineffectiveness of groups. With the shift in research questions over the years, brainstorming research is now more closely connected to the literature on creativity, both at the individual and group level. In this section, we will describe how brainstorming research is related to three other areas of inquiry: social cognition work on individual-level creativity, work on lifespan creative achievement, and work on group creativity.

4.3.1. Social cognition and individual-level creativity

The research in Phase 2 showed that there are two ways to generate many ideas: generate ideas in many categories (i.e., high category diversity) and generate many ideas in a few categories (i.e., high within-category fluency). Research in Phase 3 showed that one way to generate original ideas is to generate many ideas in one category and to explore a category in greater depth. However, generating ideas in many categories is also likely to result in original ideas, because this would increase the likelihood that ideas are generated in categories that are not routinely considered (i.e., more original categories).

De Dreu et al. (2008a) have recently argued that generating ideas in many categories requires a broad attentional focus and cognitive flexibility, whereas generating many ideas in a specific category requires a narrow attentional focus and persistence. Furthermore, they argued that flexible processing and a broad focus as well as persistent processing with a narrow focus may lead to many ideas (as Nijstad et al., 2002, had found) and to original ideas (as Rietzschel et al., 2007, had found). Finally, and most importantly, they argued that some dispositional traits and situationally induced states may relate to creativity because they associate with cognitive flexibility and a broad focus, whereas others relate to creativity because they associate with cognitive persistence and a narrow focus.

De Dreu et al. (2008a) applied these ideas to a topic within the social cognition literature: the effects of mood states on creative performance. This rather substantial literature had shown that positive mood states generally stimulate creativity (as compared to neutral states), but that the effects of negative mood states are inconsistent (see Ashby et al., 1999; Baas et al., 2008, for reviews). De Dreu et al. (2008a) argued that besides valence (positive–negative), mood states also vary in level of activation (activating–deactivating). Deactivating mood states (e.g., feeling relaxed or sad) lead to disengagement and have no relation with creativity, but activating mood states (e.g., happiness, elation, enthusiasm, anger, fear) stimulate creativity. Further, based on the cognitive tuning hypothesis (Clore et al., 1994; Schwarz & Bless, 1991), they argued that positive mood states signal a problem-free environment and lead to flexible processing and a broad attentional focus, whereas negative mood states signal a problematic environment and lead to systematic processing and a narrow attentional focus. Based on these ideas, De Dreu et al. (2008a) predicted that positive activating mood states stimulate category diversity and negative activating mood states stimulate within-category fluency. Furthermore, both high category diversity and high within-category fluency lead to greater creativity (i.e., productivity and originality of ideas). In a series of experiments, these hypotheses were confirmed.

The distinction between category diversity and within-category fluency made in Phase 2, and the connection between these measures and idea quality identified in Phase 3, thus have consequences for individual-level creativity. Therefore, it would be useful to use brainstorming tasks in future (social cognition) research on creativity and to establish whether effects are obtained because states or traits relate to category diversity or to within-category fluency.

It is interesting to note that the distinction between breadth of processing (cf. category diversity) and depth of processing (cf. within-category fluency) has also been made in other areas of research. For example, Conway et al. (2008) have recently argued that the concept of integrative complexity (a measure of the structural complexity of statements or thoughts) has two components. The first is dialectical complexity, which involves recognizing that there are tensions between different dimensions as they relate to a focal topic (e.g., recognizing that there are pros and cons associated with a decision). The second is elaborative complexity, which occurs when a singular, dominant theme is developed in a complex way (e.g., recognizing that there are multiple, related reasons why a decision is bad). While dialectical complexity seems to involve broader thinking and multiple contrasting perspectives, elaborative complexity seems to involve depth of processing within a single perspective. It may be the case that antecedents of a broad or narrow attentional focus influence the different dimensions of integrative complexity in the same way as they do the different dimensions of creative performance.

4.3.2. Lifespan creative achievement

Brainstorming research focuses on creative performance during relatively short sessions (e.g., 20 min) and mainly examines the influence of situational factors (e.g., working in groups vs. working alone, exposure to stimulus ideas) on creative performance. Another prominent line of research on creativity has quite a different focus: it looks at long-term creative achievements of eminent people (e.g., scientists or artists) and aims to explain who will make creative achievements, when these achievements are likely to be made during the lifespan, and what the career trajectories of creative people look like (e.g., [Simonton, 1997, 2003](#)). Despite the large differences in the two research traditions, there is one interesting and important parallel: the strong relation between quantity and quality.

The relation between number of ideas and number of high-quality ideas is not limited to short-term sessions, but is also found in life-time achievement. Indeed, the single most important predictor of creative eminence is productivity ([Simonton, 2003](#)). This relation holds between creators (i.e., those who are more productive are more likely to produce important works) as well as within creators (i.e., creators are more likely to produce important works in a period in which they are especially prolific; e.g., [Simonton, 1997](#)). Furthermore, the ratio between total output and quality of output does not seem to increase with total output: producing more implies producing more high-quality ideas but also producing more low-quality ideas. This phenomenon has been called the equal-odds rule: every product has an equal chance of being of high quality ([Simonton, 1997](#)). This is similar to what has been found in brainstorming work: there is a strong positive correlation between number of ideas and number of high-quality ideas, but not between number of ideas and average quality of ideas. It is also interesting to note that the hit-ratio (i.e., the number of high-quality ideas divided by the total number of ideas) does not increase over the lifespan; apparently people do not become better at recognizing their good ideas, but continue to devote their attention to “hits” as well as “misses.” This resembles the findings in brainstorming research that people are relatively poor at idea selection.

As we discussed above, one way to explain these findings is by assuming that creativity is essentially a random process. However, brainstorming research in Phase 3 has shown that there is more to the creative process than chance: when looking at ideas within categories, the average quality of these ideas does correlate with the number of ideas generated within those categories, indicating that the increase in the number of good ideas was not totally counterbalanced by an increase in the number of poor ideas. The question thus arises whether this might also be true for lifetime creative achievements. We currently do not have the answer, but two possibilities suggest themselves. First, these results may not generalize to lifetime

creativity. For example, [Simonton \(2003\)](#) suggests that a systematic approach (like surveying a category in great depth during a brainstorming session) is unlikely to result in major creative achievements, but only in relatively minor contributions. Thus, it may be the case that persistence within a specific field of inquiry and taking a systematic problem-solving approach does not yield ground-breaking creative achievements. A second possibility, however, is that these findings do generalize when individuals' contributions to specific subdomains, rather than global achievements, are assessed. Scientists, for example, may contribute to different scientific questions throughout their careers, and it is possible that productivity within these subdomains is correlated with average quality of the contributions within those subdomains.

Brainstorming research might also help our understanding of a second aspect of lifespan creative achievement, namely the decline in creativity with age. Although past performance is a much better predictor of scientific and artistic productivity than age (with individuals who are more productive at young age being also more productive in older age than their less productive colleagues), overall there is some decline in productivity with advancing age. However, the interesting feature of this decline is that it "is a function of career age, not chronological age" ([Simonton, 1997](#), p. 70). Thus, individuals who start their scientific or artistic careers at age 30 will experience their decline later than people who start in their 20s. [Simonton \(1997\)](#) explains this relation with the assumption that creators start with an "initial creative potential" which they consume during their lifetime.

Based on the ideas about creativity developed by [Rietzschel et al. \(2007\)](#), we would suggest a somewhat different interpretation. According to our model, idea generation uses the knowledge which is most accessible at any given moment and therefore most easily retrieved. We further argue that knowledge accessibility is linked to habitual thinking, because the frequent use of particular cognitive structures enhances chronic accessibility of these structures. Inevitably, artists and scientists also develop thinking habits, and these habits gain strengths with increasing years of doing research or working as an artist. Those strategies which were successful in earlier work are used again, and unsuccessful strategies are discarded. The longer we go on, the more we become prisoners of our own ideas and the less likely we are to try something different that is likely to be more innovative.

Although this habit explanation appears to be similar to Simonton's assumption of a limited "initial creative potential," there is one major difference: Whereas the initial creative potential, however great at the beginning, will inevitably decline over the course of a career, people can break their habits and start radically different and more innovative work. Because breaking habits is difficult as long as one stays in a stable environment (e.g., [Wood et al., 2005](#)), for scientists the best strategy to kick-start flagging creativity is probably to move to a new university to collaborate

with new colleagues, who have different approaches and new ideas, and/or to start working in a totally new research area. It might also be beneficial to take a sabbatical at another university, especially if one chooses a department with which one does not already have close contacts.

4.3.3. Group creativity

Much of the brainstorming research (in all three phases) has compared individual and group performance. Although this work has clearly shown that brainstorming is best performed by individuals, it still is commonly done in group settings (perhaps due to the illusion of group efficacy discussed earlier). Because teamwork is a reality in many organizations, and because there may be differences among groups in creative performance (i.e., some groups are more creative than others), it is important to investigate the factors that influence group creativity (see also Paulus & Nijstad, 2003). Some recent work has done exactly that, often applying brainstorming procedures.

Several recent studies seem to converge around the idea that group creativity requires that members engage in independent thinking rather than striving for consensus or group harmony. For example, Beersma and De Dreu (2005) first had groups perform either a *competitive* negotiation or a more friendly and *cooperative* negotiation. These groups subsequently performed a creativity task (designing marketing slogans). The groups who just finished the competitive negotiation were more creative than those who just finished the cooperative negotiation, perhaps because after a competitive negotiation, group members were more likely to distinguish themselves from the other members. Second, Nemeth and Ormiston (2007) had groups perform two idea-generation sessions. After the first session, groups either remained intact or experienced a change in group membership. Groups were more creative after they had experienced a change in membership than when membership remained stable (also see Choi & Thompson, 2005). However, people in the stable membership groups felt more comfortable than those who had experienced membership change, suggesting that stable groups focused more on group harmony, which harmed group creativity. Third, Goncalo and Staw (2006) had group members describe either why they were similar to other members (activating collectivist values) or why they were unique (activating individualistic values). Next, the groups had to generate ideas. The authors found that those groups in which individualistic values were activated were more creative than those in which collectivistic values were activated. Again, this seems to imply that differentiating oneself from the group and engaging in independent thinking leads to more creativity than assimilating and focusing on similarities.

Although these studies seem highly consistent, they raise the question why these effects were found. Given the research in Phase 2, one might assume that independent thinking is associated with category diversity rather

than with within-category fluency (and [Goncalo & Staw, 2006](#), found some evidence for this). This view would also be consistent with some findings of [Diehl \(1991\)](#); reported in [Stroebe & Diehl, 1994](#)). [Diehl \(1991\)](#) found that groups that were composed of members with diverse perspectives were more productive, and that the reason was that they surveyed more categories of ideas than homogeneously composed groups. Indeed, many authors have argued that group diversity would be associated with higher levels of creativity (see [Milliken et al., 2003](#), for a review). However, given the Phase 2 work, it might be the case that surveying more categories implies that these categories are not surveyed in great depth. This might be one reason why it has not consistently been found that diverse groups are more creative than homogeneous groups ([Van Knippenberg & Schippers, 2007](#)). More direct evidence on the effects of diversity on category diversity, within-category fluency, and idea quality would thus be desirable.

5. CONCLUSIONS

Brainstorming research has come a long way since [Taylor et al. \(1958\)](#) so dramatically disproved [Osborn's \(1957\)](#) claim about the productive benefits of group brainstorming.³ Initially, the productivity loss of brainstorming groups was approached as an issue of group productivity. Although researchers used the high correlation between originality and number of ideas as an excuse to avoid the cumbersome determination of idea originality, they were really much more interested in the quantity than the quality of group production. After all, the fact that individuals produced more ideas when working alone than when verbally interacting in groups was an extremely interesting phenomenon in its own right, regardless of whether the reduction in quantity was accompanied by a reduction in quality.

This hardly changed in what we call Phase 2 research, when cognitive theories were brought to bear on the problem.⁴ The major motivation behind the development of SIAM was to develop a testable psychological explanation for production blocking. That the theory could also explain stimulation effects was initially an unintended benefit, but one that was more and more appreciated once evidence mounted that,

³ It is interesting to note that although [Osborn \(1963\)](#) did not cite the [Taylor et al. \(1958\)](#) finding in the third edition of his book, he also did not repeat his claim.

⁴ Because our research has been determined by SIAM, we restricted our discussion of cognitive approaches to this theory. However, we should mention that [Brown et al. \(1998\)](#) had earlier developed a matrix model, which is similar to SIAM in the sense that associative processes are assumed to underlie idea generation. However, SIAM emphasizes active search processes, whereas the matrix model emphasizes the structural properties of associative networks. The matrix model has also failed to stimulate much research. We have compared the two models in an earlier publication ([Nijstad & Stroebe, 2006](#)).

under conditions which avoided blocking, idea sharing could lead to stimulation effects. However, even in the study of stimulation effects, the main interest was in the increase in the quantity of ideas that were produced. Thus, none of the studies that demonstrated stimulation effects analyzed the impact of these effects on originality of ideas. The reason given for this neglect was the conviction that quantity and quality were so closely related that it could be safely assumed that increases in quantity would be accompanied by increases in originality. But if one had really been interested in creativity, one could at least have looked at whether these stimulation effects actually extended to originality, which is one of the core dimensions of creative performance.

Our own trust in the truism that quantity breeds quality was finally shattered once we began to think more explicitly about the psychological underpinnings of this relation. The only reason we could find why this relation should be universal was a random process. If people drew their ideas from a pool of ideas, which contained an equal number of original and unoriginal ideas, the probability of original and unoriginal ideas to be drawn would be the same. However, these assumptions were inconsistent with the cognitive processes assumed by SIAM. By adding principles derived from creativity research to the search processes assumed by SIAM, we arrived at predictions about the conditions under which the quantity of ideas would be associated with the ideas' quality. According to the *path-of-least-resistance* hypothesis, increasing quantity will increase quality mainly if the increase in quantity is due to a deeper search, rather than a skimming of the surface of the pool of ideas. However, because some categories of ideas are more original than others, even increases in category diversity might result in an increase in originality (De Dreu et al., 2008a).

5.1. Some practical advice

As we mentioned earlier, brainstorming continues to be widely applied in organizations of all kinds. Indeed, it is easy to find Web sites that offer advice on how to conduct an effective brainstorming session. After 50 years of research (starting with Taylor et al.'s, 1958, first study on brainstorming effectiveness), let us give some practical evidence-based advice on how to conduct an effective brainstorming session.

1. Avoid large (verbally) interactive groups. They may appear effective, but are not. Any advice on Web sites or in other places suggesting an optimal group size of more than three is likely to be wrong (and distrust any other advice they might give). Keep these groups as small as possible (e.g., use dyads), and break up larger groups into smaller ones. When larger groups are used, use ways of interacting that do not require turn-taking among group members. If you have a computer system that

- allows for idea sharing (EBS), that is fine. However, do not buy such a system: exchanging slips of paper (brainwriting) is just as effective and a lot less expensive.
2. Having access to ideas of others in general seems to be helpful. Thus, provide access to ideas of others (e.g., in the form of written notes) and make sure that people actually pay attention to others' ideas. The potential for cognitive stimulation is likely to be greater in groups that consist of members with different areas of expertise, because they are likely to come up with different perspectives on a problem, leading to the generation of ideas in more categories. Sequential interactions between people from different backgrounds in dyadic conversations may also be very helpful.
 3. Break up larger problems into smaller ones. There are usually several approaches (e.g., categories of ideas) one can take to a problem, and idea quantity increases if all of the approaches are considered separately and sequentially. Furthermore, generating more ideas within each category is likely to lead to better ideas within that category.
 4. People tend to select conventional ideas (ideas that are feasible but not original) out of the pool of ideas generated during a brainstorming session. Therefore, in a first selection round, select only for originality. Include other quality dimensions only later, because otherwise you will end up with the same old boring ideas, which would imply that the brainstorming session was a complete waste of time.

5.2. Some final thoughts

When [Diehl and Stroebe \(1987\)](#) submitted the first draft of their article that identified production blocking as the major cause of the productivity loss in brainstorming groups, they had entitled it “Productivity loss in brainstorming groups: The solution of a riddle.” Fortunately, a wise editor (Norbert Kerr) persuaded them to change the second part of this title into “Towards the solution of a riddle.” This was a good advice, because behind every riddle hides another riddle, and as we have seen from this review, the [Diehl and Stroebe \(1987\)](#) study was no exception. The future will have to reveal which riddles are hiding behind the current review.

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REFERENCES

- Aarts, H., & Dijksterhuis, A. (2000). Habits as knowledge structures: Automaticity in goal-directed behavior. *Journal of Personality and Social Psychology*, *78*, 53–63.
- Amabile, T. M. (1983). Social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology*, *45*, 357–376.
- Ashby, F. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, *106*, 529–550.
- Baas, M., De Dreu, C. K. W., & Nijstad, B. A. (2008). A meta-analysis of 25 years of research on mood and creativity: Hedonic tone, activation, or regulatory focus? *Psychological Bulletin*, *134*, 739–756.
- Basden, B. H., Basden, D. R., Bryner, S., & Thomas, R. L. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1176–1189.
- Beersma, B., & De Dreu, C. K. W. (2005). Conflict's consequences: Effects of social motives on postnegotiation creative and convergent group functioning and performance. *Journal of Personality and Social Psychology*, *89*, 358–374.
- Brown, V., Tumeo, M., Larey, T. S., & Paulus, P. B. (1998). Modeling cognitive interactions during group brainstorming. *Small Group Research*, *29*, 495–526.
- Camacho, L. M., & Paulus, P. B. (1995). The role of social anxiousness in group brainstorming. *Journal of Personality and Social Psychology*, *68*, 1071–1080.
- Choi, H. S., & Thompson, L. (2005). Old wine in a new bottle: Impact of membership change on group creativity. *Organizational Behavior and Human Decision Processes*, *98*, 121–132.
- Clore, G. L., Schwarz, N., & Conway, M. (1994). Cognitive causes and consequences of emotion. In R. S. Wyer & T. K. Srull (Eds.), *Handbook of social cognition* (2nd ed., [Punctuation Not Allowed at the end of Element] pp. 323–417). Hillsdale, NJ: Erlbaum.
- Cohen, S., & Bailey, D. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management*, *23*, 239–290.
- Collaros, P., & Anderson, L. R. (1969). Effects of perceived expertness upon creativity of members of brainstorming groups. *Journal of Applied Psychology*, *53*, 159–163.
- Conway, L. G. III, Thoemmes, F., Allison, A. M., et al. (2008). Two ways to be complex and why they matter: Implications for attitude strength and lying. *Journal of Personality and Social Psychology*, *95*, 1029–1044.
- Cottrell, N. B. (1972). Social facilitation. In C. G. McClintock (Ed.), *Experimental social psychology*. New York: Holt.
- De Dreu, C. K. W., Baas, M., & Nijstad, B. A. (2008a). Hedonic tone and activation in the mood–creativity link: Towards a Dual Pathway to Creativity model. *Journal of Personality and Social Psychology*, *94*, 739–756.
- De Dreu, C. K. W., Nijstad, B. A., & Van Knippenberg, D. (2008b). Motivated information processing in group judgment and decision making. *Personality and Social Psychology Review*, *12*, 22–49.
- Dennis, A. R., & Valacich, J. S. (1993). Computer brainstorms: More heads are better than one. *Journal of Applied Psychology*, *78*, 531–537.
- Diehl, M. (1991). Kollektive Kreativität: Zur Quantität und Qualität der Ideenproduktion in Kleingruppen (*Collective creativity: On quantity and quality of idea production in small groups*). Germany: University of Tübingen, Unpublished Habilitationsschrift.
- Diehl, M., Munkes, J., & Ziegler, R. (2002). Brainstorming and cognitive stimulation: When does being exposed to the ideas of others facilitate or inhibit one's own idea generation? In Paper presented at the conference of the European Association of Experimental Social Psychology, San Sebastian, Spain.

- Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. *Journal of Personality and Social Psychology, 53*, 497–509.
- Diehl, M., & Stroebe, W. (1991). Productivity loss in idea-generating groups: Tracking down the blocking effect. *Journal of Personality and Social Psychology, 61*, 392–403.
- Dugosh, K. L., Paulus, P. B., Roland, E. J., & Yang, H. C. (2000). Cognitive stimulation in brainstorming. *Journal of Personality and Social Psychology, 79*, 722–735.
- Dunbar, K. (1997). How scientists think: On-line creativity and conceptual change in science. In T. B. Ward, S. M. Smith, & J. Vaid (Eds.), *Creative thought: An investigation of conceptual structures and processes* (pp. 461–493). Washington, DC: American Psychological Association.
- Faure, C. (2004). Beyond brainstorming: Effects of different group procedures on selection of ideas and satisfaction with the process. *Journal of Creative Behavior, 38*, 13–34.
- Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. Cambridge, MA: The MIT Press.
- Gallupe, R. B., Bastianutti, L. M., & Cooper, W. H. (1991). Unblocking brainstormers. *Journal of Applied Psychology, 76*, 137–142.
- Gallupe, R. B., Cooper, W. H., Grisé, M., & Bastianutti, L. M. (1994). Blocking electronic brainstormers. *Journal of Applied Psychology, 79*, 77–86.
- Goncalo, J. A., & Staw, B. M. (2006). Individualism–collectivism and group creativity. *Organizational Behavior and Human Decision Processes, 100*, 96–109.
- Harkins, S. G., & Jackson, J. M. (1985). The role of evaluation in eliminating social loafing. *Personality and Social Psychology Bulletin, 11*, 457–465.
- Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121*, 43–64.
- Ingham, A. G., Levinger, G., Graves, J., & Peckham, V. (1974). The Ringelmann effect: Studies of group size and group performance. *Journal of Experimental Social Psychology, 10*, 371–384.
- Kerr, N. L., & Bruun, S. E. (1983). Dispensability of member effort and group motivation losses: Free-rider effects. *Journal of Personality and Social Psychology, 44*, 78–94.
- Lamm, H., & Trommsdorff, G. (1973). Group versus individual performance on tasks requiring ideational proficiency (brainstorming): A review. *European Journal of Social Psychology, 3*, 361–388.
- Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology, 37*, 822–832.
- Maginn, B., & Harris, R. (1980). Effects of anticipated evaluation on individual brainstorming performance. *Journal of Applied Psychology, 65*, 219–225.
- Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220–232.
- Milliken, F. J., Bartel, C. A., & Kurzberg, T. R. (2003). Diversity and creativity in work groups: A dynamic perspective on the affective and cognitive processes that link diversity and performance. In P. B. Paulus & B. A. Nijstad (Eds.), *Group creativity: Innovation through collaboration* (pp. 32–62). New York: Oxford University Press.
- Mullen, B., Johnson, C., & Salas, E. (1991). Productivity loss in brainstorming groups: A meta-analytic integration. *Basic and Applied Social Psychology, 12*, 3–23.
- Nemeth, C. J., & Ormiston, M. (2007). Creative idea generation: Harmony versus stimulation. *European Journal of Social Psychology, 37*, 524–535.
- Nijstad, B. A. (2000). *How the group affects the mind: Effects of communication in idea generating groups*. Utrecht: Utrecht University, Unpublished doctoral dissertation.
- Nijstad, B. A., & De Dreu, C. K. W. (2002). Creativity and group innovation. *Applied Psychology: An International Review, 51*, 400–406.

- Nijstad, B. A., & Stroebe, W. (2006). How the group affects the mind: A cognitive model of idea generation in groups. *Personality and Social Psychology Review, 10*, 186–213.
- Nijstad, B. A., Stroebe, W., & Lodewijkx, H. F. M. (2002). Cognitive stimulation and interference in groups: Exposure effects in an idea generation task. *Journal of Experimental Social Psychology, 38*, 535–544.
- Nijstad, B. A., Stroebe, W., & Lodewijkx, H. F. M. (2003). Production blocking and idea generation: Does blocking interfere with cognitive processes? *Journal of Experimental Social Psychology, 39*, 531–548.
- Nijstad, B. A., Stroebe, W., & Lodewijkx, H. F. M. (2006). The illusion of group productivity: A reduction of failures explanation. *European Journal of Social Psychology, 36*, 31–48.
- Olson, M. (1965). *The logic of collective action*. Cambridge, MA: Harvard University Press.
- Osborn, A. F. (1953). *Applied imagination*. Oxford, UK: Charles Scribner's.
- Osborn, A. F. (1957). *Applied imagination* (2nd ed.). New York, NY: Charles Scribner's.
- Osborn, A. F. (1963). *Applied imagination* (3rd ed.). New York: Charles Scribner's.
- Parnes, S. J., & Meadow, A. (1959). Effects of "brainstorming" instructions on creative problem solving by trained and untrained subjects. *Journal of Educational Psychology, 50*, 171–176.
- Paulus, P. B., & Dzindolet, M. T. (1993). Social influence processes in group brainstorming. *Journal of Personality and Social Psychology, 64*, 575–586.
- Paulus, P. B., & Nijstad, B. A. (Eds.), (2003). *Group creativity: Innovation through collaboration*. New York, NY: Oxford University Press.
- Paulus, P. B., Dzindolet, M. T., Poletes, G., & Camacho, L. M. (1993). Perception of performance in group brainstorming: The illusion of group productivity. *Personality and Social Psychology Bulletin, 19*, 78–89.
- Paulus, P. B., & Yang, H. C. (2000). Idea generation in groups: A basis for creativity in organizations. *Organizational Behavior and Human Decision Processes, 82*, 76–87.
- Perkins, D. N. (1981). *The mind's best work*. Cambridge, MA: Harvard University Press.
- Putman, V. L., & Paulus, P. B. (in press). Brainstorming, brainstorming rules and decision making. *Journal of Creative Behavior*.
- Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review, 88*, 93–134.
- Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2006). Productivity is not enough: A comparison of interactive and nominal brainstorming groups on idea generation and selection. *Journal of Experimental Social Psychology, 42*, 244–251.
- Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2007). Relative accessibility of domain knowledge and creativity: The effects of knowledge activation on the quantity and originality of generated ideas. *Journal of Experimental Social Psychology, 43*, 933–946.
- Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2009). *Problem Scope and Idea Selection*. Unpublished manuscript.
- Rietzschel, E. F., Nijstad, B. A., & Stroebe, W. (2010). The selection of creative ideas after individual idea generation: Choosing between creativity and impact. *British Journal of Psychology, 101*, 47–68.
- Roemer, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin, 76*, 45–48.
- Rosenthal, R. (1995). Writing meta-analytic reviews. *Psychological Bulletin, 118*, 183–192.
- Schwarz, N., & Bless, H. (1991). Happy and mindless, but sad and smart? The impact of affective states on analytic reasoning. In J. P. Forgas (Ed.), *Emotion and social judgments* (pp. 55–71). Elmsford, NY: Pergamon Press.
- Simonton, D. K. (1997). Creative productivity: A predictive and explanatory model of career trajectories and landmarks. *Psychological Review, 104*, 66–89.

- Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: The integration of product, process, and person perspectives. *Psychological Bulletin*, *129*, 475–494.
- Stasser, G., & Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology*, *48*, 1467–1478.
- Stein, M. I. (1975). *Stimulating creativity: Group procedures*. Oxford, UK: Academic Press.
- Steiner, I. D. (1972). *Group process and productivity*. New York: Academic Press.
- Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3–15). Cambridge: Cambridge University Press.
- Stroebe, W. (1981). Social loafing and the economic theory of public goods. First International Conference on Social Processes in Small Groups Kill Devil Hills, NC: Nags Head Conference Centre.
- Stroebe, W., & Diehl, M. (1994). Why groups are less effective than their members: On productivity losses in idea-generating groups. In W. Stroebe & M. Hewstone (Eds.), *European review of social psychology*, (Vol. 5, pp. 271–303). London: Wiley.
- Stroebe, W., Diehl, M., & Abakoumkin, G. (1992). The illusion of group effectivity. *Personality and Social Psychology Bulletin*, *18*, 643–650.
- Stroebe, W., & Frey, B. (1982). Self-interest and collective action: The economics and psychology of public goods. *British Journal of Social Psychology*, *21*, 121–137.
- Sutton, R. I., & Hargadon, A. (1996). Brainstorming groups in context: Effectiveness in a product design firm. *Administrative Science Quarterly*, *41*, 685–718.
- Taylor, D. W., Berry, P. C., & Block, C. H. (1958). Does group participation when using brainstorming facilitate or inhibit creative thinking? *Administrative Science Quarterly*, *3*, 23–47.
- Valacich, J. S., Dennis, A. R., & Connolly, T. (1994). Idea-generation in computer-based groups: A new ending to an old story. *Organizational Behavior and Human Decision Processes*, *57*, 448–467.
- Van Knippenberg, D., & Schippers, M. C. (2007). Work group diversity. *Annual Review of Psychology*, *58*, 515–541.
- Ward, T. B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology*, *27*, 1–40.
- Ward, T. B., Patterson, M. J., Sifonis, C. M., Dodds, R. A., & Saunders, K. N. (2002). The role of graded category structure in imaginative thought. *Memory and Cognition*, *30*, 199–216.
- Weldon, M. S., & Bellinger, K. D. (1997). Collective memory: The nature of individual and collective recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1160–1175.
- West, M. A. (2002). Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups. *Applied Psychology: An International Review*, *51*, 355–387.
- West, M. A., & Anderson, N. (1996). Innovation in top management teams. *Journal of Applied Psychology*, *81*, 680–693.
- Wood, W., Tam, L., & Witt, W. (2005). Changing circumstances, disrupting habits. *Journal of Personality and Social Psychology*, *88*, 918–933.
- Zajonc, R. B. (1965). Social facilitation. *Science*, *149*, 269–274.
- Ziegler, R., Diehl, M., & Zijlstra, G. (2000). Idea production in nominal and virtual groups: Does computer-mediated communication improve group brainstorming? *Group Processes and Intergroup Relations*, *3*, 141–158.