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Abstract: Much of human behavior involves subconscious cognition that can be manipulated through "priming"—the presentation of a stimulus designed to subconsciously implant a concept in working memory that alters subsequent behavior. Priming is a well-known phenomenon for individual behavior, but we do not know

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whether priming can be used to influence group behavior. We developed a Web-based computer game that was designed to improve creativity through priming. Participants were exposed to a priming game and then worked as members of a group using electronic brainstorming (EBS) to generate ideas on a creativity task. Our results show that when users played the game, designed to improve performance, their groups generated significantly more ideas that were more creative than when they were exposed to neutral priming. Our findings extend the literature by providing evidence that individual priming substantially affects group idea generation performance. Avenues for future research include designing EBS software that optimizes group ideation through priming, examining the conditions under which priming has the most substantial impact on ideation performance, and examining whether priming can be used to enhance other group processes (e.g., convergence tasks).

Key words and phrases: collaboration, creativity, electronic brainstorming, idea generation, individual cognition, priming, virtual groups.

Virtual groups are increasingly prevalent in today's organizations [15, 73]. Research on the efficiency and effectiveness of virtual group interactions has become an important component of the study of collaboration [24, 39]. Improving creativity and idea generation is also important to organizations [20, 36, 44]. Many organizations are turning to novel approaches to spark creativity, including gathering unique ideas from people both internal and external to the organization [27]. When these groups use various tools, such as e-mail, Web chat, instant messenger, social media, and videoconferencing, to brainstorm, the process is referred to as "electronic brainstorming" (EBS). EBS can generate innovative ideas that can transform existing business paradigms [20, 36, 69]. Research on collaboration has shown that virtual groups can quickly use EBS to improve their performance [25, 44].

Most prior EBS research has focused on social psychology based factors (i.e., the interaction among participants), such as anonymity, group size, and proximity [25]. Relatively few studies have examined how individual cognition affects virtual group performance [37, 42, 72], even though prior research has established the importance of individual differences in influencing information system usage and performance (see [46]). Research on individual cognition during group collaboration has examined the cognitive demands placed on groups by technologies [2, 42], and the role of cognition in collaboration [31, 47, 67]. However, we are not aware of any studies that have attempted to *predispose* individual cognition to *enhance* the performance of virtual groups.

There is considerable research in psychology showing that much of human behavior uses subconscious cognition [5, 8]. Research in information systems has established that subconscious cognition influences constructs important to the study of information systems, such as behavioral intention and perceptions of ease of use [52]. Our research, however, shows the importance of subconscious cognition in shaping our behavior when using information technology.

One approach to influencing subconscious cognition is priming. Priming is the presentation of a stimulus designed to activate in working memory certain mental representations of concepts, attitudes, or beliefs that then influence the individual's behavior on a subsequent task [6]. The effects of priming on individual behavior have been extensively studied in psychology [3, 6, 60, 65]. Individuals can be primed in a number of ways, including exposure to words, pictures, sounds, or, as in this study, a computer game.

Priming has been used in the human–computer interaction literature to study the behavior of individuals in a virtual setting [13, 51]. These studies have utilized a special type of priming, known as "supraliminal" or "above threshold" priming. With supraliminal priming, an individual is aware of the stimulus, but he or she is unaware of the intent of that stimulus [6, 22]. A few studies have found that priming can influence group behavior. Postmes et al. [56], for example, found that priming could influence group behavior in computer-mediated communication. They found that anonymous groups primed with prosocial norms produced solutions that were more socially influenced solutions than those primed with efficiency norms. Priming can be designed to influence an individual's affect, attitudes, or behavior [6].

In this paper, we present a study examining the impact of priming the concept of achievement on performance of EBS groups. We found that groups produced significantly more unique ideas and more creative ideas following the achievement priming. The effect sizes were large, with most Cohen's *d* above 0.80. To put this into perspective, these effect sizes are as large as the one observed in using EBS technology versus verbal brainstorming [25].

Prior Theory

Creativity and Electronic Brainstorming

Idea generation is often performed by formal or informal groups [36]. A group's primary objective in idea generation is to produce creative ideas with an ultimate goal of creating a set of possible ideas that can be further evaluated and, eventually, implemented [28, 36]. Overall creativity and ideation performance can be measured using either the quantity or creativity of ideas generated [26]. Quantity of ideas is usually measured as the total number of unique ideas generated by a group. The creativity of unique ideas can be conceptualized on a number of different dimensions, such as novelty, workability, relevance, and specificity [21]. Each of these dimensions illustrate a different aspect of the overall creativity of an idea [21]. In some situations, it is desirable to generate a large quantity of ideas, whereas other situations require a few highly creative ideas [18].

Verbal brainstorming has been used for more than half a century as a technique for improving idea generation performance [23, 49]. Organizations use brainstorming sessions as an important way to develop creative ideas [70]. Early research argued that four practices improved the effectiveness of verbal brainstorming: (1) producing a large quantity of ideas, (2) ruling out criticism, (3) freewheeling (wild/weird ideas) must be accepted, and (4) combining and improvising ideas should be encouraged [53].

EBS involves the use of technology such as e-mail, browser-based systems, text-based chat, group support systems, or vendor-specific tools to support the brainstorming process [35]. It has been shown through multiple research studies that use of EBS results in better idea generation performance than verbal interaction [25]. This result is robust even in small EBS groups [24]. Furthermore, larger groups using EBS also have been shown to perform as well as nominal groups [24, 55]. While there has been debate around the size of the EBS group required to outperform nominal groups (see [24, 55]), there is consensus in the literature that EBS groups outperform verbal groups [25]. EBS captures the best elements of verbal brainstorming by allowing group members to share ideas and build on them [34]. EBS also minimizes the effect of production blocking since the group members work simultaneously on their own computer screens and are not blocked from contributing ideas [50]. EBS also can be anonymous, which may encourage more idea generation since group members may be less apprehensive when contributing ideas [23, 35]. However, anonymity can diffuse responsibility and dehumanize the discussion, which can increase social loafing (i.e., freeloading) [1]. Social loafing can be mitigated by social comparison—the process of showing the progress of the group collectively in real time [62].

Most prior research on EBS (and virtual group performance in general) has focused primarily on social interactions and how technology can help or hurt the sharing of ideas to improve or impair performance [37, 59]. More recently, research has begun to examine individual characteristics and individual cognition as important factors influencing the success of EBS and other group processes [2, 40, 42]. For example, EBS performance is affected by group member characteristics such as domain knowledge, cognitive ability, personality type, and creative skill [54]. Similarly, group performance has been shown to be influenced by the interface of an EBS tool [62]. Yet research on what factors of the interface could enhance individual cognition in virtual groups remains limited.

Prior research on idea generation has looked at the various processes in the mind that take place during the actual production of an idea as well as the factors that support or inhibit these processes. Nijstad and Stroebe's [48] search for ideas in associative memory (SIAM) model proposed idea generation as a two-staged cognitive process, with the first stage being the activation of knowledge and the second stage being the actual idea production in the mind [48]. Ideas suggested by other group members help activate knowledge relevant to the problem, but production blocking (the need to wait to take turns during verbal brainstorming) interferes with both cognitive stages [48].

Priming and Individual Cognition

The first link in our theoretical chain is the effect of priming on individual cognition and behavior. Priming is the activation of internal mental representations in an attempt to influence subsequent behavior [6]. The degree to which individual behavior can be influenced through priming visual objects, goals, or stereotypes has been well documented in psychology research [6, 7]. Priming research has shown that influencing individual behavior, attitudes, or beliefs can be done by activating the mental representations underlying the desired behavior, attitudes, or beliefs [4, 32, 64]. Once an individual's mental representations have been activated, subsequent behavior is influenced. Priming research has illustrated the ability to improve individual cognition, thereby improving performance on individual tasks [8, 33].

Priming research began with a study on creativity that described the tendency of individuals to use prior notions of how objects should be used to complete tasks [30]. These prior notions inhibited one's creativity. However, when an individual witnessed a novel use of an object immediately preceding a creativity task, the individual was more likely to use a novel approach in completing his or her task [30]. Initially referred to as "perceptual readiness," the term "priming" was later coined by Segal and Cofer [61] in reference to a phenomenon in which participants exposed to words in one task were more likely to use those words in subsequent tasks [16]. In later studies, the idea of priming was developed to describe the activation of mental representations to influence future individual responses [6].

There are two predominant ways to deliver priming: subliminal ("below threshold") and supraliminal ("above threshold"). Subliminal priming involves a brief presentation of a stimulus followed by a perceptual mask [6]. In this case, the stimulus is presented quickly and the participant is not consciously aware of that stimulus. In contrast, with supraliminal priming, the participant is consciously aware of the stimulus, but is not aware of its intent. The common feature of both subliminal and supraliminal priming is that the participant is unaware that the stimulus is activating mental representations [6].

There are many different ways individuals can be primed. Semantic priming—priming delivered using words—is believed to work by activating semantic networks within the brain. The brain is organized into networks based on the associations one makes during prior experiences [45]. Semantic networks develop as we begin to interact with the world and form a basis of semantic memory that is interconnected with our previous associations of core objects, concepts, or beliefs. The *association* between words is more important in activating mental representations than any particular word [43]. The use of priming consequently spread into social psychology when researchers illustrated the ability to prime concepts and categories, not just individual words [38]. For example, priming the word "popcorn" is likely to activate semantic networks associated with eating and semantic networks associated with movies because most people are aware that popcorn is usually popular in movie theaters. Thus, if we prime the word "popcorn" and then ask individuals to name celebrities, they would be more likely to name movie stars than rock stars because the semantic network associated with movies is active in working memory and the semantic network associated with music is not. As one might expect, activation of semantic networks through priming is not permanent; priming effects decay over time [6].

Researchers have found that priming can trigger goals outside of awareness [8]. In one experiment, researchers used a word search puzzle to prime the concept of achievement [8]. In that study, individuals received either priming semantically related to achievement (e.g., *compete, win, succeed*) or neutral words (e.g., *ranch, carpet, shampoo*). Individuals primed with achievement performed better in subsequent tasks than individuals exposed to the neutral prime [8]. Bargh et al. [8] argue that achievement priming improves performance by introducing a subconscious goal of achievement into participants' working memory. This subconscious goal works in exactly the same manner as a conscious goal, motivating behavior and thus influencing performance.

We argue that achievement priming works by activating the semantic networks associated with higher performance. Semantic networks are distributed nodes of information in conceptual schema represented in the brain [71]. These networks are activated and brought into working memory automatically, without conscious thought, when attributes of the object concept are evoked [71]. However, the activation of these networks is transient and will decrease over time. We theorize that when the semantic networks associated with achievement are activated in working memory by a priming stimulus, the individual subconsciously experiences an increase in the expectancy of achievement for the subsequent task. This increase in the expectancy of achievement influences behavior by increasing individual idea generation and improving creativity.

Individual Priming Effects on Group Performance

The second link in our theoretical chain is how the impact of priming on individual cognition and behavior influences group performance. While some studies have primed individual achievement (see [8]), we are aware of no study that has attempted to improve group performance by using individual priming.

Idea generation is an additive task [68] in that each group member's contributions add to the contributions of others to form the task output. Unlike a decision task, there is no need for the group to come to an agreement on an idea generation task. Therefore, we argue that increased individual idea production is likely to have a direct effect on the group output and performance [68]. As an individual produces more ideas and shares them with the group, the total production of ideas increases. It is possible that these additional ideas will also create synergy and trigger other group members to produce more ideas, but this is not essential to our arguments. Improved individual performance will be additive to overall group performance regardless of whether they create greater performance through enhanced synergy within the group.

Therefore, we hypothesize that individual exposure to an achievement prime will improve the performance of a virtual group performing an idea generation task. In other words, groups will produce more unique ideas following exposure to the achievement prime than when the group is exposed to a neutral prime designed to have no effect on group performance. Thus,

> *Hypotheses 1: An EBS group will generate more unique ideas when group members are individually primed for achievement than when groups are individually primed with a neutral prime.*

The number of ideas is only one aspect of performance; idea creativity is also often important [18, 26]. We argue that any intervention that increases the number of ideas is likely to have similar effects on the creativity of the ideas generated. Prior research has established a positive correlation between quantity of ideas and creativity of ideas [11, 12].

A highly creative idea should have three characteristics: the idea should be applicable, effective, and implementable to the problem at hand. In addition, the fourth dimension, idea novelty, is defined by how rare, unusual, or uncommon an idea is [19, 21]. Dean et al. [21] used this approach to define their four dimensions of creativity: workability, relevance, specificity, and idea novelty.

The workability dimension consists of the subdimensions acceptability and implementability [21]. The acceptability of an idea describes the level to which an idea does not violate known constraints. Implementable ideas are ideas that can be easily applied to solve the problem [21]. The relevance dimension consists of the subdimensions applicability and effectiveness [21]. Ideas are applicable if they clearly relate to part of the stated problem. Ideas that are effective clearly solve all or part of the stated problem [21]. The specificity dimension consists of the subdimensions completeness and implicational explicitness [21]. Completeness describes the number of independent subcomponents into which an idea can be decomposed and the breadth of its coverage. Implicational explicitness describes the degree to which there is a clear relationship between the suggested action and its expected outcome [21]. Finally, the novelty dimension of Dean et al. [21] defines idea novelty by two subdimensions: originality and paradigm relatedness. Original ideas include ideas that are rare and have the characteristic of being ingenious or imaginative. The paradigm relatedness subdimension refers to ideas that are transformational and germinal with the ability to change the way a problem is viewed [21].

In this paper, we focus on three of the four dimensions of creativity: novelty, workability, and relevance. The specificity dimension was omitted because, during the coding of the data, we generalized ideas into a master idea list that was common across groups. Therefore, this process intentionally reduced the specificity of the ideas to less-specific ideas that could be coded on creativity across the other three dimensions.

While individual exposure is expected to increase the number of ideas generated by activating semantic networks related to achievement, we also assert that activation of these semantic networks will increase the creativity of ideas produced by individuals. Thus, individual exposure to a supraliminal achievement prime should improve performance of a virtual group by increasing the novelty, workability, and relevance of ideas that individuals generate during an EBS task. Therefore,

Hypothesis 2a: An EBS group will produce ideas of greater novelty when group members are individually primed for achievement than when they are individually primed with a neutral prime.

Hypothesis 2b: An EBS group will produce ideas of greater workability of ideas produced when group members are individually primed for achievement than when they are individually primed with a neutral prime.

Hypothesis 2c: An EBS group will produce ideas of greater relevance of ideas produced when group members are individually primed for achievement than when they are individually primed with a neutral prime.

Method

Participants

One hundred seventy-five sophomores and juniors were drawn from an introductory business course and received extra credit for participating in the study. The average age of the participants was 19.6 years with a standard deviation (SD) of 1.51. Fifty-seven percent of the participants were male. The participants worked in 35 groups of five members each.

Task

The participants performed two different idea generation tasks, each lasting 15 minutes. In one task, the participants generated ideas to increase tourism within the state. In the other task, the participants generated ideas to reduce pollution. The participants were instructed to generate as many ideas as possible and to build on the ideas of others in the group.

The participants used the group chat room in the Sakai Learning Management System to work together to generate ideas. This software is similar to other group chat software in that there is one lower window in which participants type ideas, with a larger scrolling window on top in which the ideas contributed by group members are displayed. Although the participants were working as a group through the chat software, they were sitting in separate cubicles in front of individual personal computers during the entire study so no verbal communication occurred.

Treatments

There were two treatments: achievement priming and neutral priming. The experimental design was a fully counterbalanced repeated-measures design. All of the groups performed both treatments, with the treatment order and task order randomly assigned to the groups.

The treatments were delivered through a computer game using a modified version of scrambled sentence priming [14] in which participants developed a four word newspaper headline from a set of five words [66]. This supraliminal priming technique has been used extensively over the past 20 years to deliver semantic priming to individual participants [7, 14, 63].

A screenshot of the Word Game is provided in Figure 1. The priming game presented a set of five words, from which participants chose four words to create a newspaper headline. After a participant was satisfied with his or her choice of four words, the participant clicked a submit button and a new set of five words was presented. The participants played the priming game for eight minutes or until they completed 30 sets of priming words. Approximately 80 percent of the participants were still working on the priming game after eight minutes elapsed.

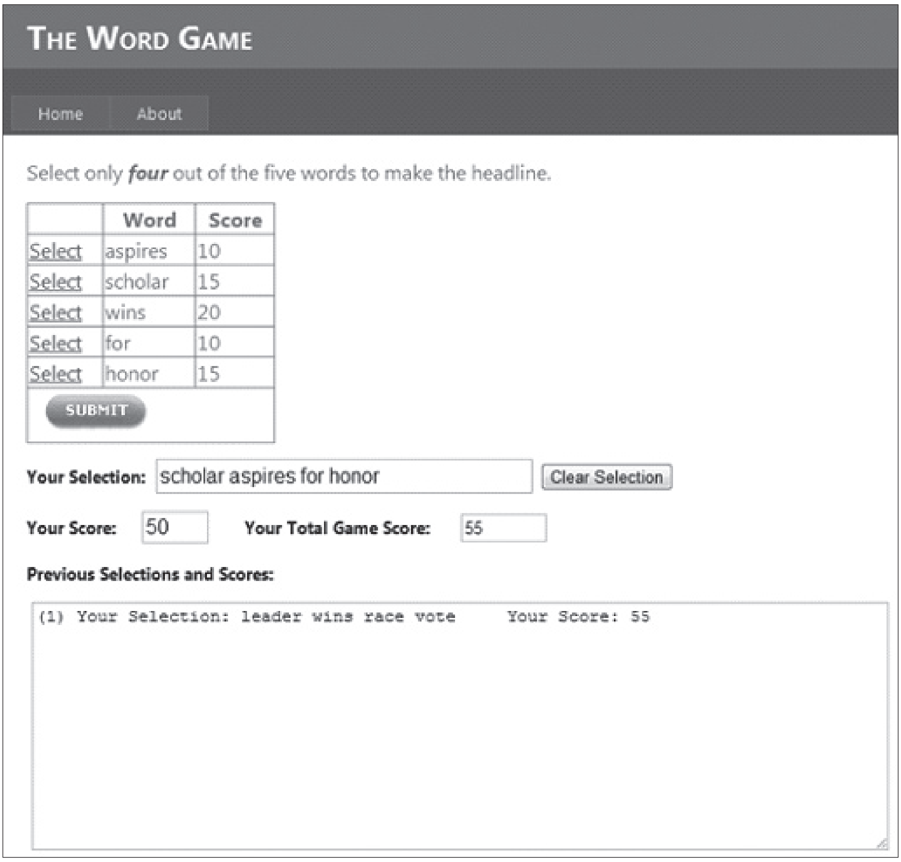

Figure 1. Screenshot of the Priming Word Game

The achievement priming treatment was designed to prime the concept of "achievement" while the neutral priming treatment was designed to have no effect. In the achievement priming treatment, one or two words in each set of five words was an achievement-oriented word based on words used in a prior achievement activation priming experiment [8]. These words include *win, leader, strive, aspire, scholar, genius, award,* and *honor.* The neutral words were chosen to have no effect and were drawn from the same prior research [8]. These words include *worker, break, room, leaves, bench, dirt, dwell,* and *table.*

The words for both the achievement and neutral priming treatment were validated for arousal and valence using the affective norms of English words (ANEW) database [10]. This database presents normative emotional ratings in terms of arousal and valence for thousands of English language words. Arousal is rated on a scale from 1 (low arousal) to 9 (high arousal) and valence is rated from 1 (negative) to 9 (positive). Both priming conditions had 150 words each (30 sets of five words each). The neutral priming words were moderate in arousal (M = 4.44, SD = 0.75) as well as in valence (M = 4.89, SD = 0.59). The achievement priming words had higher arousal (M = 5.73, SD = 0.98) and more positive valence (M = 7.22, SD = 0.93). The achievement priming words significantly differed from the neutral priming words on both arousal ($t(248) = 13.19$, $p < 0.001$) and valence ($t(298) = 25.74$, $p < 0.001$).

Dependent Measures

The primary dependent measure was idea generation performance, measured at the group level in two primary ways. The first measure was the number of unique ideas. Two raters independently analyzed the chat transcripts and identified and counted the number of unique ideas generated by each group. The raters were instructed to identify all of the unique (i.e., nonredundant) ideas proposed in each transcript. Chat transcripts for three sessions of the pollution and three sessions of the tourism tasks were analyzed. Each rater came up with a total number of unique ideas for each of the transcripts. In total, the raters agreed on 147 of 152 unique ideas. Therefore, interrater reliability was 96.7 percent (calculated as 1 – (number of differences/total codings)).

The second performance construct was idea creativity. We first created a master idea list of all the ideas mentioned by all of the groups and then assessed the creativity of each idea on the list. There are many different ways to assess idea creativity [9, 57]. We used the approach of Dean et al. [21]. We used three of their dimensions: novelty, workability, and relevance.

The three dimensions consisted of six subdimensions. Ideas in the master idea list were scored on each of the six subdimensions. Two raters independently scored the first 25 ideas from both the tourism and pollution master idea list on each of these six subdimensions. A total of 300 creativity ratings were obtained. The raters agreed on 284 of 300 ratings. Therefore, interrater reliability was 94.6 percent. Cronbach's alphas were obtained for each of the three dimensions based on their two subdimensions. Novelty encompassed originality and paradigm relatedness ($\alpha = 0.88$), workability encompassed acceptability and implementability ($\alpha = 0.74$), and relevance encompassed applicability and effectiveness ($\alpha = 0.85$).

There are several ways of calculating idea creativity [58]. We used two different approaches. The first, total creativity, measures the overall creativity of all the ideas produced by a group [58]. To produce the novelty score for each group, we summed the novelty score for each idea generated by the group (i.e., the average of the scores for its two submissions). We used the same process for the workability score and relevance score. Each group received a separate novelty, workability, and relevance score.

The second approach to measure creativity counted only the number of ideas rated as highly creative [58]. The Dean et al. [21] scale ranges from 1 to 4 on each of its dimensions. To obtain only the ideas high in creativity, we counted only the ideas coded as 3 or above for each dimension. We then counted the total number of highly creative ideas produced by each group based on their novelty, workability, and relevance. Each group received a separate novelty, workability, and relevance score.

Procedures

The experiment employed a repeated-measures design. The participants began by individually playing one of the priming games for eight minutes; each of the participants in a group received the same priming treatment, either achievement or neutral. The participants then worked with the other members of their group using the chat software to generate ideas on one of the tasks, either tourism or pollution. Next they completed a short survey asking age and gender as well as a personality questionnaire as a "distractor" task. The participants then repeated these same steps (priming game, idea generation) for the second treatment and task. The participants were debriefed and the session concluded.

Results

All the statistical analyses were completed using SPSS PASW Statistics 18.0. A repeated-measures general linear model (GLM) was used to examine the differences between the achievement and neutral priming conditions.[1] A summary of the results is provided in Table 1.

Unique Ideas

The groups produced significantly more unique ideas following the achievement priming game than the neutral priming game ($F(1, 32) = 22.73$, $p < 0.001$). The effect size was large, with Cohen's $d = 0.89$. The order in which the groups received priming conditions did not affect the number of unique ideas generated ($F(1, 32) = 2.18$, $p = 0.150$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.064$, $p = 0.802$). H1 was supported.

Creativity of Ideas

The groups produced ideas of significantly higher total novelty following the achievement priming game than the neutral priming game ($F(1, 32) = 22.23$, $p < 0.001$). The effect size was large, with Cohen's $d = 0.88$. Once again, the order in which the groups received the priming conditions did not affect the novelty of ideas produced ($F(1, 32) = 0.598$, $p = 0.45$), nor did the task order for the pollution or tourism task ($F(1, 32) = 0.129$, $p = 0.722$). The groups produced a greater number of novel ideas following the achievement priming game than the neutral priming game ($F(1, 32) = 13.36$, $p = 0.001$). The effect size was medium, with Cohen's $d = 0.67$. The order in which the groups received the priming conditions did not affect the number of novel ideas produced ($F(1, 32) = 0.264$, $p = 0.611$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.187$, $p = 0.668$). We conclude that H2a was supported.

The groups produced ideas of significantly higher total workability following the achievement priming game than the neutral priming game ($F(1, 32) = 17.82$, $p < 0.001$). The effect size was large, with Cohen's $d = 0.82$. The order in which the

Table 1. Means, Standard Deviations, and Results of Statistical Analyses

		Achievement prime		Neutral prime			
Measures	*N*	Mean	Standard deviation	Mean	Standard deviation	*F*	*p*-value
Number of unique ideas	35 groups	37.71	11.83	28.11	9.60	22.73	< 0.001
Total novelty score	35 groups	72.07	27.49	51.40	18.83	22.23	< 0.001
Number of novel ideas	35 groups	8.41	5.50	5.39	3.31	13.36	0.001
Total workability score	35 groups	128.07	41.39	97.23	33.37	17.82	< 0.001
Number of workable ideas	35 groups	32.71	10.82	24.71	8.68	18.89	< 0.001
Total relevance score	35 groups	108.89	34.50	82.86	28.25	19.01	< 0.001
Number of relevant ideas	35 groups	29.27	9.82	22.24	8.14	13.61	0.001

groups received the priming conditions did not affect the workability of ideas produced ($F(1, 32) = 2.15$, $p = 0.152$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.004$, $p = 0.953$). The groups produced a greater number of workable ideas following the achievement priming game than the neutral game ($F(1, 32) = 18.89$, $p < 0.001$). The effect size was large, with Cohen's $d = 0.82$. The order in which the groups received the priming conditions did not affect the number of workable ideas produced ($F(1, 32) = 2.067$, $p = 0.160$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.002$, $p = 0.962$). We conclude that H2b was supported.

The groups produced ideas of significantly higher total relevance following the achievement priming game than the neutral priming game ($F(1, 32) = 19.01$, $p < 0.001$). The effect size was large, with Cohen's $d = 0.83$. The order in which the groups received the priming conditions did not affect the relevance of ideas produced ($F(1, 32) = 2.454$, $p = 0.127$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.138$, $p = 0.713$). The groups produced a greater number of relevant ideas following the achievement priming game than the neutral priming game ($F(1, 32) = 13.61$, $p = 0.001$). The effect size was medium, with Cohen's $d = 0.78$. The order in which the group received the priming conditions did not affect the number of relevant ideas produced ($F(1, 32) = 2.290$, $p = 0.140$), nor did the task order for the pollution and tourism task ($F(1, 32) = 0.001$, $p = 0.980$). We conclude that H2c was supported.

Discussion

Our study provides evidence that a supraliminal priming computer game played by an individual affects the number and creativity of ideas produced in a subsequent group EBS task. We found that groups that received an achievement prime preceding the EBS task produced more unique ideas that were more novel, workable, and relevant than ideas produced by the same group using EBS following a neutral prime.

The effect size of the achievement prime for the number of ideas and total creativity of the ideas is what Cohen [17] would call "large," with Cohen's d ranging from 0.82 for total relevance to 0.89 for number of unique ideas. The effect sizes of the achievement prime for number of highly creative ideas ranged from "medium" to "large" with Cohen's d ranging from 0.67 to 0.82. To provide context, these effect sizes are as large as the effect size observed in using collaboration technology. For example, Dennis and Wixom [25] reported an effect size of 0.81 for small groups using EBS and 1.09 for large groups using EBS when compared to verbally interacting groups [25]. Thus, priming has the same magnitude of effect as EBS itself. It should be noted that in this research, we used small EBS groups of five individuals. While small groups do not necessarily outperform nominal groups, the literature shows that small groups outperform verbal groups [24, 25].

There are two important theoretical linkages to this priming effect: the impact of priming on individual behavior and the impact of this individual behavior on group processes and outcomes. First, at the individual level, we believe the achievement prime subconsciously activated the participants' semantic network associated with achievement, and thus the participants had increased expectations of achievement.

We used a supraliminal achievement prime to subconsciously activate the semantic network and increase the expectancy of achievement.

One of the challenges in priming research lies in demonstrating the cognitive mechanism by which it works. Priming occurs at a subconscious level, so individuals who are primed are not aware they are behaving differently and when questioned will exhibit no knowledge of the change in behavior or the influence of priming [8]. So although we offer this theoretical linkage as an explanation of why the effect occurs, participants, if asked, would not be aware of any increased expectation of achievement; and if they were aware, then it would suggest that priming was not the cause because priming works subconsciously, not consciously [7].

Second, at the group level, we believe that improved individual idea production improves group performance. Because idea generation is an additive task [68], each individual's contributions directly add to the contributions of others to form the task output. When one group member contributes a new idea, it has a direct benefit to the total group idea production (presuming, of course, that the idea does not inhibit the production of ideas by others). Thus, improved individual performance is directly translated into improved group performance.

Prior research has highlighted a need for research on individual cognition and its contribution to group performance [37, 47]. Research is beginning to investigate the impact of individual cognition on the processes and outcomes of computer-supported group work [2, 31, 42]. This study moves this research one step further by showing that individual cognition can be intentionally influenced to enhance group performance, at least for additive tasks such as idea generation. This finding highlights the importance of understanding—and actively manipulating—individual cognition during group collaboration.

One important limitation of our research is that we studied only two primes, an achievement prime and a neutral prime. We used these two primes because they have been extensively used in past research. Nonetheless, it is possible that these primes have unique effects that are not generalizable, or that our neutral prime was in fact not neutral and somehow impaired the performance of groups.

Despite these limitations, we believe that this study opens a new door in collaboration research. We found that a relatively simple, short, and subtle manipulation produced substantial effects on group EBS performance. If playing a simple computer priming game prior to group work has such a large impact on group work, what other pre–group work activities, both intentional and unintentional, have significant effects on group performance? We believe that these results have important implications for both research and practice.

Implications for Research

First, our research shows that priming individuals for achievement improves subsequent group performance on an idea generation task. We argued that there is a two-part theoretical linkage: priming to individual performance and individual performance to group performance. Because individual performance is directly linked to group performance for additive tasks, one important question for future research is whether this linkage from individual to group performance works for other group tasks that are not additive. For example, can group decision-making performance be influenced by priming, and if so, what type of priming is most conducive to decision-making tasks? Understanding the precise effects of priming and its boundary conditions on group behavior is important given the large effect sizes in this study. Furthermore, research should examine whether the results of individual priming aggregate to the group level in an additive or multiplicative fashion (e.g., does the increased performance of one individual trigger a synergistic increase in performance in other group members?). In this research, we are unable to disentangle whether individual priming has an additive or a multiplicative effect.

Second, the other theoretical linkage is from priming to individual behavior. This study examined one form of priming delivery designed to influence individual behavior: a scrambled sentence computer game. Future research should examine the effects of other priming delivery techniques. It might be inefficient or unrealistic to expect individual group members to perform a scrambled sentence computer game before each group process. Research should examine the efficacy of building priming into the information systems that groups will use so that priming is delivered in real time as the group uses the technology. For example, Gmail routinely embeds advertising on the same screen the user works on. Priming words could be added to (or replace) this advertising. Even if the user did not consciously attend to the words, they could still have an impact [29]. The effect of such real-time priming may be even stronger than the preevent priming used in this study; the priming would be integrated into the flow of activities, so the user would receive a steady stream of priming, which would help prevent the prime from wearing off.

Third, our study used words to induce priming, but there are many other techniques, such as pictures or music, that could be imbedded into an information system. For example, organizations have started to use three-dimensional (3D) virtual environments, such as Second Life or OpenWonderland, to foster collaboration among virtual groups [39, 41]. In addition to the visually pleasing virtual space, many of these environments offer EBS tools. Research should examine the applicability of priming using the visual and auditory abilities of these 3D environments. Three-dimensional virtual worlds have the capability of incorporating visual cues into the task environment. Future research could focus on the use of visual priming, that is, the placing of objects in the visual space to induce priming. Would designing a 3D virtual environment to prime achievement through a visual prime have similar effects as using word-based games to deliver semantic primes, as we did in this study? Such visual priming could have stronger effects as the priming would persist during the performance of the task. Finding the effects of visual priming in 3D virtual environments could have important implications for the design of virtual environments.

Fourth, if the goal of achievement can be primed, what other goals and behaviors might be primed? For example, are concepts such as cooperation, mindfulness, or thoughtfulness capable of being activated via a supraliminal prime? In contrast, can less desirable behaviors be primed, such as impulsivity or selfishness? If so, what are the implications—ethical and otherwise—of priming these concepts? It might be possible to develop task-specific forms of priming so that we prime creativity for EBS tasks, quality for decision-making tasks, fairness for distributive tasks, and so on. We believe that our results call for more research on different types of priming that can be used to influence group behavior and performance for a variety of tasks.

Finally, this study contributes to social and cognitive psychology as well as information systems research by showing that priming an individual affects overall group performance. Much of the priming literature has focused on the individual-level cognitive effects of priming. Our study shows that priming at the individual level affects performance at the group level. Future research should focus on how priming affects group interactions above and beyond virtual group environments. More research is needed to understand what proportion of group members needs to be primed in order to influence group behavior and performance. For example, does priming three of five group members produce the same results as priming all five group members? If so, what is the nature of the priming effect in this setting? The primed group members might perform better than the nonprimed group members or, alternatively, the primed group members might influence the group dynamic such that all group members perform better.

Implications for Practice

We believe that the results presented in this study have several practical implications for organizations. First, priming has such a large effect on idea generation performance (as large as using EBS technology in the first place) that the principal implication is to integrate achievement priming into the process of EBS. By combining EBS and priming we can effectively double the impact of EBS over verbal brainstorming. Integrating priming into EBS not only would lead to more unique ideas but also would help improve idea creativity. Organizations also employ different kinds of EBS tools to improve the idea generation performance of their groups. Organizations can think of innovative ways to integrate priming into the EBS tool. One would expect that repeated use of priming in organizations would enable group members to become aware of the purpose of the priming. However, research has shown that priming works even when participants are aware of its purpose [6].

Second, to maximize group performance, it is desirable that group members get quickly motivated and engaged in the virtual setting. Building an achievement prime into collaboration tools might help the members achieve more during group tasks. Priming could be used to achieve a higher level of group engagement. Priming can be integrated into the collaboration tool by means of a pretask or training task. With primes smoothly integrated into collaboration tools, group performance might be influenced in a latent way, without the need for managers to deliberately build priming activities into group processes.

Third, this paper used an intentional prime, but many activities we engage in on a daily basis may unintentionally prime us. Individual experiences prior to group meetings can influence performance within those meetings. For example, a bad telephone conversation prior to an important meeting might unintentionally prime an individual and affect subsequent performance within the meeting. It could also lead to the group member having a negative viewpoint about the ideas put forward by other group members, thus affecting the performance of the group as a whole. Managers must be cognizant of unintentional priming before meetings. The group leader could ask other group members to do a priming task before they start the EBS activity as a way of "clearing" such unintentional priming and better ensuring that group members are in the desired mind-set when they begin the activity, thus leading to better group performance.

Finally, we believe this study has several practical implications for the design of the information technology artifact. If primes can be smoothly integrated into the design of an information system, then user behavior could be intentionally influenced. One potential implementation of this could be in the use of advertising in information system design. Advertisements are prevalent on Web sites and other online services, including collaboration and social media (e.g., Gmail, Skype, Facebook). Primes might be developed to influence a user's interactions or perceptions of an online service. Incorporating advertisements with the intent to prime users could influence user productivity by subconsciously activating goals within the user. Alternatively, primes could be developed to influence an individual's usability perceptions, which organizations could use in Web site design to make individual users more likely to adopt the technology.

Conclusion

EBS performance has been a focus of many research studies over the past 25 years. Its benefits and limitations have been well studied, and research has concluded that it adds considerable value compared to verbal brainstorming [25]. In this study, we investigated the effect of achievement priming delivered through a computer game on group idea generation performance. Groups exposed to achievement priming generated more ideas and ideas that were more creative than groups that were exposed to neutral priming. The size of this effect was as large as using EBS rather than verbal brainstorming, suggesting that priming has a major impact on performance. We believe that the results of this study open many avenues for future research to explore different types of priming and their effects on group behaviors and performance. We also believe that organizations can use the results of this study to improve the idea generation performance of their virtual groups.

Note

1. To control for the differences between the pollution and tourism tasks, we performed an analysis using the standardized value for each measure. This was done by calculating the z-score for the number of unique ideas, novelty, workability, and relevance. The statistical results using standardized values did not differ from the results using unstandardized values (because both tasks were evenly distributed across both treatments), so we chose to use the nonstandardized values for simplicity of presentation.

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