2016 49th Hawaii International Conference on System Sciences

Opening the Mind: Designing 3D Virtual Environments to Enhance Team Creativity

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Abstract

3D virtual environments (VEs) have emerged as a popular collaboration tool because they enable richer forms of collaboration than traditional text- or Web-based tools. Research on text-based electronic brainstorming (EBS) has shown it is possible to increase idea fluency and creativity through priming, the use of stimuli to implant concepts in working memory designed to influence subconscious cognition and ultimately behavior. In this experiment, we designed a 3D VE to prime for "openness" (i.e., broad attentional scope) and examined the effects it had on idea fluency and creativity in EBS sessions. Our results show that virtual teams generated more ideas of greater creativity when they brainstormed in a VE specifically designed to prime openness than in a closed environment.

1. Introduction

Virtual teams are commonplace in today's organizations [9, 49]. Companies have also increased the use of 3D virtual environments (VEs) in product development and for virtual teams [2]. Meanwhile, more focus has been placed on the role of individual cognition in virtual team interactions [30] with some studies indicating that individual cognition can be influenced to enhance the productivity of the team [15]. VEs are unique in that they can be fairly easily customized to encourage their use as collaborative spaces. However, little research has examined the ability to design a VE to enhance individual cognition. More research is needed to examine ways VEs can be designed in order to enhance individual cognition, thus improving overall team performance.

One way VEs can be designed to influence individual cognition is by integrating priming into the environment [3]. Research in the information systems field has shown priming can increase idea generation by as much as 30 percent [15], indicating that an individual prime can have profound influence on the productivity of the overall team. However, few studies have attempted to leverage the customizability of VEs to prime individuals and improve team processes. One recent study found that placing objects relating to creativity in the 3D environment improved team creativity [6]. However, study of incorporating primes into 3D virtual environments remains limited, as does our understanding of their potential impacts on team creativity.

In this study, we examine if the design of a 3D virtual environment can be used to deliberately influence the scope of attention during electronic brainstorming (EBS) and thus increase team creativity. Previous research has shown that priming a broad versus narrow scope of attention can improve individual creativity [24]. The activation of broad attentional scope (i.e., "openness") is hypothesized to improve creative performance in EBS by creating an open virtual space that in turn increases the feeling of spaciousness. Our findings indicate that VEs can be designed to prime individuals and thereby increase creative performance compared to traditional VE designs. These findings have significant theoretical and practical implications for research on both VE design and collaboration.

2. Prior theory

2.1. 3D Virtual Environments

3D virtual environments are simulated environments that parallel the real world and provide a locus of interaction for participants [38]. These environments provide 3D representations of objects and users [10]. Avatars, or digital representations of self that are controlled by the users, can move throughout the space and interact with objects and other users. VEs enable participants to communicate through text-based chat, gestures, and voice [20]. Some VEs also offer special-purpose tools to support collaboration. For example, *Open Wonderland*, a Java open source toolkit for creating collaborative 3D worlds, offers users a "sticky pad" to communicate and exchange information in the same way they could use a whiteboard in face-to-

1530-1605/16 $31.00 © 2016 IEEE
DOI 10.1109/HICSS.2016.38

face interactions. VEs such as *ProtoSphere*™ and *Second Life*™ integrate Web applications such as social networks, blogs, and Microsoft Office. Thus VEs offer richer collaboration than commonly used tools like email and instant messaging [38].

Research on 3D VEs has shown that they are used in a variety of ways. In a review of 46 published VE articles, 62% of VEs were found to be a simulation of a real space, while 23% of VEs were found to be designed solely as a communication space [35]. These findings indicate that the design of most VEs is done to imitate a real physical space, rather than focusing on using the technology to intentionally improve the collaborative experience. Research has begun to examine some aspects of influencing creativity by VE design, including advantages of VE compared to face-to-face communication [23], allowing teams to co-construct their environment [22], and using objects associated with creativity to improve team collaboration [6]. However, the aim of this study is to incorporate a theory-driven approach to design, utilizing prior literature on priming and behavior.

In a VE, the work space can be redesigned and adapted relatively easily, especially when compared to the cost and effort required to redesign a physical workspace. Organizations often spend significant financial resources and time creating physical collaborative spaces within their physical office facilities [37]. Researchers in psychology have studied the impacts of workplace design on overall productivity and creativity, and have discovered that work space design has an important connection to increasing performance [28, 34]. However, designing (and redesigning) physical spaces to meet the needs of a specific collaborative task could become prohibitively expensive for the organization. Therefore, given the inherent customizability of VEs, it is essential to understand how VEs can be designed in a way that leverages the creativity of the team and increase its overall productivity.

2.2. Electronic brainstorming

Extensive research on brainstorming has been conducted over the last half century [see, for review, 33]. Since it was first described in 1954, brainstorming has been utilized by organizations to generate alternatives for both simple and complex problems [33, 40]. A team's primary objective in idea generation is to produce creative ideas that can be further evaluated and implemented. In organizations, teams exist in a variety of different formations (e.g., formal versus informal, large versus small), yet idea generation is a prevalent team activity in all configurations [19].

Teams can engage in brainstorming in a variety of ways (e.g., verbal, electronic). Verbal brainstorming has been used for more than a half century [15]. Osborn argued that a verbal brainstorming exercise should have four guidelines: (a) producing a large quantity of ideas, (b) criticism must be ruled out, (c) freewheeling (wild ideas) must be accepted and (d) combination and improvisation on ideas should be encouraged [40].

There is an extensive body of literature on idea generation in virtual teams [see, 18], establishing that teams using electronic brainstorming outperform face-to-face teams in idea fluency and creativity [7, 17]. Idea fluency is generally measured as the total number of unique ideas generated by a team. Creativity of ideas can be conceptualized on different dimensions, such as novelty, workability, relevance, and specificity [14]. Goals of virtual teams can vary with some teams requiring high idea fluency and other teams requiring only a few highly creative ideas [12].

Electronic brainstorming (EBS) involves the use of technology (e.g., e-mail, browser based systems, text-based chat) to facilitate the brainstorming process [26]. It has been shown that the use of EBS results in better idea generation performance than verbal interaction [18]. EBS captures the best elements of verbal brainstorming by allowing team members to share and build on ideas [25]. EBS also minimizes the effect of production blocking and offers increased anonymity, which have been shown to increase brainstorming performance [39]. In addition, EBS systems allow individual team members to scroll back through previously generated ideas at any point [16].

More recently, EBS research is examining individual characteristics and cognition as important factors influencing the success of EBS in team processes [1, 36]. For example, EBS performance is affected by team member characteristics such as domain knowledge, cognitive ability, personality type and creative skill [41]. Similarly, performance has been shown to be influenced by the EBS tool interface [44].

Priming has been used to induce greater productivity in EBS [15, 42]. Priming is the activation of mental representations, which attempt to influence subsequent behavior [3, 15]. However, these studies have not integrated the prime into the EBS tool but, rather, prime the individual in an a priori fashion (i.e., before they begin the brainstorming task). In Dennis et al [15], priming increased idea production and creativity, producing similar effects sizes as the EBS technology itself compared to face-to-face brainstorming. Thus, individual cognition can impact both the fluency and creativity of the idea generation performance of a team. Research on priming in EBS is in its infancy, with a handful of studies showing it can have significant and meaningful impacts on team creativity.

2.3. Priming, attention, and creativity

Priming research has existed for several decades and has been studied in a variety of contexts. The degree to which individual behavior can be influenced through priming visual objects, goals, or stereotypes has been well-documented in the psychology literature [3, 4]. In the beginning, priming was referred to as "perceptual readiness." When an individual witnessed a novel use of an object immediately preceding a creativity task, the individuals were more likely to use a novel approach to complete their task [21]. The term priming was later coined by Segal and Cofer [43] in reference to a phenomenon where participants exposed to words in one task were more likely to use those words in subsequent tasks [11].

More recent experiments found that priming various constructs led to more creative solutions. In one experiment, the researchers exposed participants to an undifferentiated linguistic construction (e.g., "box of tacks") or a differentiated linguistic construction (e.g., "box and tacks"). Participants exposed to the differentiated linguistic construction were more likely to differentiate further stimuli using "and." For example, if the participants were exposed to a picture of a tray of tomatoes they would be more likely to describe the picture as "a tray and tomatoes" [31]. These findings shed light on the relative ease by which individuals can be "primed" to respond to certain stimuli in a particular and predicted manner.

There are two predominant ways to deliver a prime: subliminal ("below threshold") and supraliminal ("above threshold"). Subliminal priming involves brief presentation of a stimulus followed by a perceptual mask [3]. In subliminal priming the stimulus is presented quickly and the participant is not consciously aware of that stimulus. In contrast, in supraliminal priming, the participant is consciously aware of the stimulus, but the participant is not aware of the intent behind it. The common feature in both subliminal and supraliminal priming is that the participant remains unaware that the stimulus is activating internal mental representations [3].

Many different aspects of behavior and cognition can be primed from concepts such as "achievement" to goal-oriented behavior to attention. Negative priming refers to an increased latency in attending to a specific area when the individual was previously ignoring that area [48]. For example, in a negative priming experiment, an individual must attend to a target stimulus and ignore other stimuli. When a target stimulus appears in an area where an ignored stimuli previously existed, an individual takes longer to recognize that stimulus [48]. Furthermore, when a target stimulus appears in the same location as a previous target stimulus, an individual responds more quickly [48]. Thus, priming can increase or decrease an individual's attention.

Interestingly, priming a broad or narrow scope of perceptual attention (e.g., visuospatial attention) has also been shown to create an analogous broad or narrow focus of conceptual attention (e.g., creative generation) [24]. Visuospatial refers to an individual's perception of objects and the relationships among those objects. In Friedman et al [24], participants were primed with a broad or narrow attentional scope by being required to attend to the number "3" on a computer monitor. In the experiment, nine digits (0-9) were displayed in various locations on the screen for 1 second, and the participant was required to answer a follow-up question on whether the number "3" had appeared on the screen. In the broad attentional scope condition, these digits were dispersed across a 9 *x* 13 inch computer monitor. In the narrow scope condition, the numbers appeared within a 2-inch radius of the center of the screen. After the individual had been primed with a broad or narrow scope of attention, they were required to perform a creativity task (generating alternate uses of a brick). Individuals primed with a broad scope of attention performed better in the creativity task than individuals primed with a narrow scope of attention [24].

The Friedman et al. study [24] shows that priming a broad or narrow perceptual attention induces a corresponding broad or narrow conceptual attention in a subsequent creativity task When conceptual attention has a narrow focus, a limited range of concepts are called to mind. However, when conceptual attention is broadly focused, a wide range of concepts are accessible in memory [32]. Conceptual scope can be influenced in a variety of ways, not only in the manner of Friedman et al [24]. For example, one study primed using objects within categories of narrow focus (e.g., farm animals) and broad focus (e.g., all animals) [27]. Priming farm animals elicited narrow conceptual attention, while priming with all animals elicited broad conceptual attention [27].

Several studies have examined different designs of physical spaces and their effects on individual creativity. Windows are thought to improve creativity by inducing thoughts of openness and spaciousness rather than confinement, thereby inducing a more broad scope of attention than a room without windows [8, 45, 46]. Horizontal area and height also influence perceived openness and spaciousness, which also influences creativity [46]. Other studies have examined creative environments and found color, lighting, and environment can affect creativity of individuals and

Figure 1. Screenshot of the open space in the 3D virtual environment

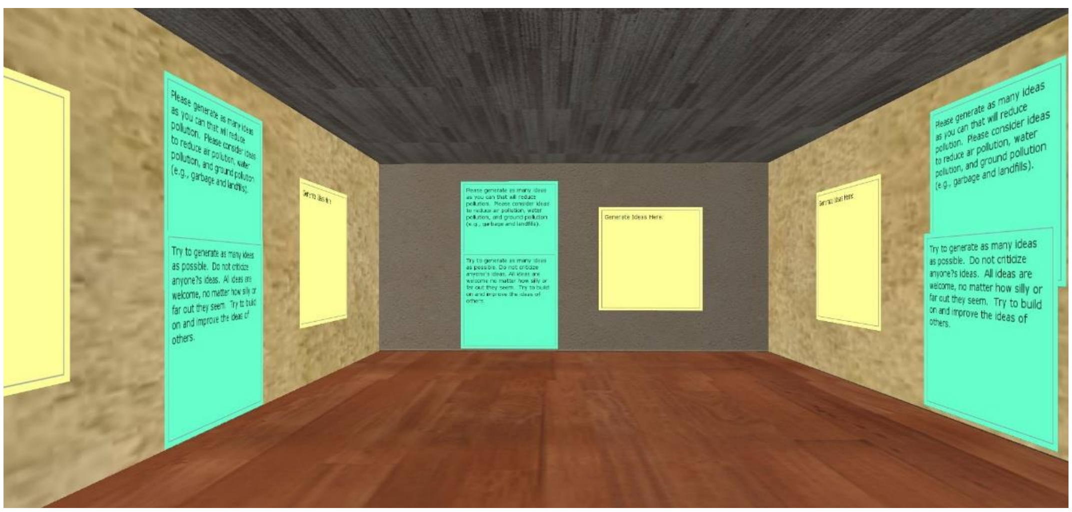

Figure 2. Screenshot of the closed space in the 3D virtual environment

teams [5, 8, 47]. While these studies have examined the effects of openness in a physical space, no studies have examined openness in a VE and its effects on creativity.

Given all this, the aim of this study is to examine whether priming openness in the design of a VE can affect team creativity. This study examines whether a 3D virtual space can be designed to facilitate creative ideation in electronic brainstorming. Two VEs were designed. The first environment provided a perceptually broad or open virtual space, while the second was a room provided by the VE software and provides a narrow or closed virtual space (see Figures 1 and 2).

In summary, we hypothesize that the broad virtual space will prime the concept of openness, which, as shown in previous studies, will induce participants using the VE to have greater idea fluency and creativity than participants in the narrow virtual space. In software design parlance, the only manipulation presented in this study is a change in the "chrome" (i.e., the visual presentation of the virtual space); there were no functional differences. The changes to the background are hypothesized to change cognition so that individuals exposed to open spaces produce more creative ideas than those in a closed space. Stated formally:

H1: Teams generating ideas in a perceptually open environment will generate more ideas than teams generating ideas in a perceptually closed environment.

In addition to increasing the overall fluency of ideas, priming a broad scope of attention is expected to increase the creativity of the ideas through the same theoretical mechanism as increasing idea fluency. Many organizations have turned to teams to solve problems or design new products [13]. In Dean et al. [14], idea creativity is conceptualized as a multi-dimensional construct, consisting of four dimensions. These four dimensions are novelty, workability, relevance, and specificity [14]. Each dimension has two sub-dimensions. These four dimensions relate to different aspects of creativity. For example, the novelty dimension refers to how original the idea is, while the relevance dimensions refers to the degree to which the idea actually applies to the specific problem domain.

The design of the open VE was intended to prime broad attentional scope. This form of priming has been shown to increase creativity in previous experiments [see 24, 45, 46]. In a similar manner, we expect the perceptually open VE to increase the creative generation of the team by creating a sense of openness that increases novelty, workability, and relevance of ideas generated during EBS. Stated formally:

H2: Teams generating ideas in a perceptually open environment will generate more a) novel, b) workable, and c) relevant ideas than teams generating ideas in a perceptually closed environment.

3. Method

3.1. Participants

One hundred forty 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 19.8 years with a standard deviation of 1.78. Fifty-five percent of the participants were male. The students worked in 36 teams. Each team consisted of four members.

3.2. Task

We used a repeated measures design in which 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, participants generated ideas to reduce pollution. The participants were instructed to generate as many ideas as possible, and build off the ideas of others in the team.

For both tasks, teams used *Open Wonderland*, the Java open source toolkit for creating collaborative 3D environments. The platform offered a set of tools, including "sticky pads" (or notepads) that enabled each team member to generate ideas on a given task. The sticky pads are somewhat similar to the GroupSystems Electronic Brainstorming (EBS) tool, in that there are different sets of ideas that are presented to participants in turn. There were blue and yellow notepads. The blue notepads contained the task instructions and could not be edited by the participants. The yellow notepads were where the participants generated ideas. Each participant was assigned to one yellow pad and was instructed to use it to record ideas. Every 3 minutes, the participants were instructed by the experimenter over voice tool in the VE to rotate to a new notepad and were further instructed to build off the ideas of the other team members written on the pad. Individual team members could not interact verbally within the environment, but were confined to writing on brainstorming pads and rotating to a new pad every three minutes.

3.3. Treatments

There were two treatments: open environment and closed environment. All teams participated in both environments, with both the treatment order and task order randomly assigned to the teams.

As shown in Figures 1 and 2 (respectively, the open and closed environments), despite the VEs having a different appearance, the amount of space the participants had to move around was held constant in both treatments. Therefore, any effect on idea fluency or creativity would be from the appearance of the environment, not the result of differences in space.

The open priming treatment was designed to prime the concept of "openness"—i.e., broad attentional scope, while the standard meeting room was a "closed" environment, which should prime a narrower attentional scope. As hypothesized, we believe the openness prime will activate a broad attentional scope which will translate into a broad conceptual scope (i.e., idea fluency and creativity) [24], which will improve the virtual team's performance on EBS tasks.

3.4. Dependent measures

The primary dependent measure was idea generation performance, measured in four ways. The first was the number of ideas generated (i.e., fluency). The ideas generated on the notepads were analyzed to count the number of unique ideas (i.e., non-redundant) generated by each team. Two raters independently counted the number of unique ideas generated by each team. Inter-rater reliability, calculated as the number of ideas on which the raters agreed, divided by the total number of ideas counted, was 96.7 percent.

The quality of ideas generated was measured using three aspects using three dimensions of Dean et al. [14] novelty, workability, and relevance, each of which had two sub-dimensions. Each idea on the master idea list was rated for all six sub-dimensions. By its nature, the use of a master idea list generalizes ideas to similarly related ideas. Therefore, the specificity dimension in Dean et al. [14] was purposely omitted.

Table 1. Means, standard deviations, and results of statistical analyses

Measures	n	Open VE		Closed VE		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	36 teams	35.56	13.20	33.56	12.85	4.77	0.036
Novelty Score	36 teams	13.12	2.54	11.59	2.98	5.50	0.022
Workability Score	36 teams	29.85	9.32	25.12	10.27	4.19	0.045
Relevance Score	36 teams	27.24	9.02	22.78	8.23	4.80	0.032

Two raters independently scored the first 25 ideas from both the tourism and pollution reduction master idea list on each of these six sub-dimensions. Coders were trained on how to code creativity on each sub-dimension using the Dean et al. [14] coding instructions. For the tourism idea generation task, 25 ideas were rated for the six sub-dimensions, resulting into a total of 150 ratings. Similarly, for the pollution-reduction idea generation task, 25 ideas were rated for the six sub-dimensions, resulting into 150 ratings. Cumulatively, a total of 300 quality ratings were obtained across the two tasks. The two raters agreed on 284 of 300 ratings. Therefore, inter-rater reliability was 94.6 percent. Cronbach's alphas were obtained for each of the three dimensions based upon their two sub-dimensions. Novelty was comprised of originality and paradigm relatedness (α = .84), workability was comprised of acceptability and implementability (α = .82), and relevance was comprised of applicability and effectiveness (α = .76).

3.5. Procedures

Participants arrived at the study and were assigned to separate physical rooms. Each room was equipped with a desktop computer running the 3D VE. The participants wore headphones and received verbal training from the research coordinator on how to use the VE. This study used a repeated measures design. Each team participated in an EBS session in both the open and closed VE. The tasks (i.e., tourism or pollution) and treatments (i.e.., open or closed) were counterbalanced to eliminate order effects. Participants began by performing one task using one treatment. The task instructions were read aloud at the beginning of the task and included the traditional EBS instructions to generate as many ideas as possible, do not criticize anyone else's ideas, and try to build off of the ideas of the other team members. The participants did not interact over voice and the avatar provided was generic, thus the production blocking and anonymity benefits of EBS were retained. When this task was completed, participants were moved to the other treatment environment and performed the second task. They were then debriefed and the session concluded.

3.6. Analyses

All statistical analyses were performed in SPSS PASW Statistics 21.0. A MANOVA was used with follow-up ANOVAs to examine differences between the open and closed VEs.

4. Results

A summary of the results is provided in Table 1. The MANOVA found an overall significant difference in the creativity between the open and closed VEs across the set of four creativity dependent variables ($F(3, 31) = 90.58$, $p < .001$; Wilk's $\lambda = .102$, partial $\eta^2 = .357$). Follow-up ANOVAs were conducted on each of the four creativity dependent variables; see below.

4.1. Unique ideas

Hypothesis 1 was supported. Teams produced significantly more unique ideas in the open VE ($F(1, 33) = 4.77$, $p < .036$). The effect size was small with Cohen's $d = .15$. The order the team received the VE treatments did not affect the number of unique ideas generated ($F(1, 33) = 1.18$, $p = .285$), nor did task order ($F(1, 33) = 1.18$, $p = .285$).

4.2. Quality of ideas

Hypothesis 2a was supported. Teams produced significantly more novel ideas in the open VE ($F(1, 33) = 5.50$, $p = .022$). The effect size was medium with Cohen's $d = .55$. Again, the order the team received the VE treatments did not affect the novelty of ideas produced ($F(1, 33) = 2.13$, $p = .154$), nor did task order for the pollution and tourism task ($F(1, 33) = 1.15$, $p = .291$).

Hypothesis 2b was supported. Teams produced significantly more workable ideas in the open VE (F(1,

33) = 4.19, $p = .045$). The effect size was small with Cohen's $d = .48$. The order the team received the VE treatments did not affect the workability of ideas produced ($F(1, 33) = 2.25$, $p = .143$), nor did task order for the pollution and tourism task ($F(1, 33) = 1.52$, $p = .226$).

Hypothesis 2c was supported. Teams produced significantly more relevant ideas in the open VE ($F(1, 33) = 4.80$, $p = .032$). The effect size was medium with Cohen's $d = .52$. The order the team received the VE treatments did not affect the relevance of ideas produced ($F(1, 33) = 2.05$, $p = .162$), nor did task order for the pollution and tourism task ($F(1, 33) = 1.66$, $p = .207$).

5. Discussion

Our study shows that using a 3D VE designed to prime "openness" (i.e., a broad scope of attention) increased idea fluency and creativity compared to a traditional VE. The two 3D VEs were functionally identical; there were no differences in the size, shape or capabilities provided. The sole difference was the absence of visual walls and roof. With respect to the music artist Pharrell Williams who suggests in his hit song *Happy*, that a "room without a roof" can induce emotion, we have experimentally shown that that "a room without a roof" can induce greater creativity.

This finding is important for both collaboration and psychology research. For collaboration research, it shows that priming can be delivered successfully in a 3D VE by simply changing the visual design of the work environment. Our results show that one specific approach to VE design (openness) improves performance. Given the inherent customizability of 3D VEs, there are a multitude of other design approaches that warrant investigation. While "openness" is a simple and useful concept, what other concepts can be primed through the design of the VE? We believe these findings have significant implications for future research, design, and practice.

For psychology research, our findings show that priming the concept of "openness" through the work environment can improve team creativity. While it may be argued that the environment (i.e., windows and plants) of the open space might influence idea generation on the pollution task, we did not observe an interaction between the pollution task and open room. Thus, evidence supports that the open space improves creative generation by priming a concept of "openness." Our research also shows that priming does not have to occur before the task of interest, as has been traditionally done; it can be delivered concurrently with the performance of the task. Second, it shows that priming openness warrants future research.

5.1. Implications for research

We believe this research provides many avenues for future research. First, our study shows that the design of VE influences the creativity of the team. Our study also suggests that the findings on increasing creativity in psychology research can be applied in design of VEs and likely will translate into increased ideation and creativity. Our research provides strong evidence that VEs can be designed intentionally to impart concepts (broad versus narrow conceptual thinking) and can help shape subconscious thought. Perhaps more importantly, our findings indicate that priming can occur concurrently with the task. Previous research has treated priming in an *a priori* fashion. Specifically, an individual would receive a prime and *then* perform a task. This experiment indicates that individuals can be primed concurrently. That is, a prime can be embedded *within* a task. This finding shows that priming can be integrated into team collaboration and not require additional time or take time away from the task at hand.

Second, the concept of openness or spaciousness is useful in creating VE needed to increase creativity. The theoretical mechanism through which this works should be studied further. With the increased use of neuroimaging tools in the information systems field, it would be useful to confirm the mechanism by examining attentional scope and creativity in the VE. For example, electroencephalography (EEG) could examine if the open VE environment creates increased activity in creative regions of the brain (e.g., right frontal cortex). The open VE likely creates a broad attentional scope through creating perceived spaciousness. This attentional scope would also translate to a broad conceptual scope, which is closely tied with increased creative production [24]. This proposed mechanism could be examined using EEG or functional magnetic resonance imaging (fMRI). Upon confirmation that this is the correct mechanism of action, EEG or fMRI could be done on participants to examine the VE design that creates the biggest effect on the regions of the brain associated with increased activation in creative regions of the brain (i.e., those activated by the "open" VE).

Third, since this study indicates that concepts introduced in a virtual space can increase productivity and creativity, it begs the question of what other concepts can be primed to affect performance in teams. Research can examine concepts that might be useful to concurrently prime in conveyance tasks (i.e., brainstorming) or convergence tasks (i.e., decision making). In Dennis et al [15], for example, participants performed a game that primed, in an a priori fashion, the concept of "achievement." Research could examine whether the achievement prime, if integrated into the 3D virtual environment, could concurrently prime the team members as they participate in EBS. Other findings in priming could also be examined. Individuals have been primed to feel youthful, be more mindful, or to feel happy. These findings could be examined in 3D VEs to see if they might impact creative generation of teams.

Similarly, it would be useful to examine priming's influence on convergence tasks, such as decision making. Research should examine if priming a broad scope of attention influences the team's ability to reach consensus. It is unclear whether broad conceptual attention or open mindedness might improve or hinder a teams' ability to reach consensus. Rather, it might be more beneficial in convergence tasks to prime a concept of teamwork or cooperativeness to enhance performance on convergence tasks.

Fourth, this study indicates that VE designers should not merely focus on functionality when creating collaborative environments; rather, they should also focus on the subconscious concepts that might be influenced by the design of the VE itself. In other words, the designer should take time to think through how the created environment might unintentionally influence an individual. If they identify certain unintentional influences their environment might have, they should examine how these might increase or decrease the performance of collaborators. Therefore, this study shows we must examine how to alter the design process of VEs to incorporate a design phase that examines unintentional influences of the environment on the individual or the team. Given the nascent nature of VEs as collaboration platforms for business enterprises, this added phase may help produce more instances of how the technology can actually benefit work.

Finally, more research is needed on the intentional design of VE to make concepts more accessible in memory. Given that VEs are easily customized, it would be easy to examine the effect of both context-dependent spaces (e.g., brainstorming on reducing pollution in a pristine pollution-free VE) and context-independent spaces (brainstorming on reducing pollution in the generic open space created in this study). Comparing content-dependent and context-independent spaces may further elucidate the best VE for a given brainstorming task and help researchers create design guidelines for specific tasks performed in VEs. VE researchers could also examine the research on physical work spaces and creativity [29, 45, 46] to see if there are further ways to create a VE that influences creativity.

5.2. Implications for practice

This study provides several insights for practice. First, the study found that openness (i.e., "room without a roof") is a useful design principle in VE design for creativity. Design of VEs for conveyance tasks, such as EBS, should be done in environments that allow the participant to feel open. Using closed spaces or traditional "conference room" type settings for EBS in VEs hinders the productivity of the team. Instead, teams should have a perceptually open space to perform creative generation tasks.

Managers should also consider the visual redesign of both physical and virtual workspaces to improve creativity. When redesigning a workspace it is important to consider what small changes can be made that could lead to increased productivity. Including windows and other objects, such as plants, have been shown to influence creative production. Redesigning physical and virtual spaces that incorporates a careful evaluation of what is included or excluded in the space could have important implications for the productivity of teams within the organization.

6. Conclusion

Research on understanding ways to enhance productivity of virtual teams remains an important topic in the collaboration literature. In this study, we integrated previous findings in priming and EBS to design a 3D VE that enhanced productivity of the overall team. The results suggest that priming a broad attentional scope improves idea fluency and creativity of the overall team. The results of this study open many avenues for future research on designing collaborative tools with primes integrated within the technology. Organizations can use the results of this study to improve EBS performance of virtual teams in 3D VEs.

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