Presence and Memory:
Immersive Virtual Reality Effects on Cued Recall

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Abstract

Presence, the psychological experience of "being there," is an important construct to consider when investigating the impact of mediated experiences on cognition. Though several studies have investigated the influence of presence on the memory of virtual environments (i.e. recalling virtual objects), few have tested how presence impacts memory on subsequent tasks in the physical world. Thirty-three male and female college students were exposed to a pro-environmental message in an immersive virtual environment. After the virtual reality treatment, they completed a memory task in the physical world regarding pro-environmental principles. Results showed a significant negative association between levels of reported presence in the virtual world and the number of correct water conservation examples remembered in the physical world. These findings suggest that media technology that induces presence can influence an individual's ability to remember information in the physical world. Possible theoretical explanations of how presence may negatively impact cognition are presented.

Keywords: **presence, memory, cued recall, free call, virtual reality**

In a media technology saturated world, people are jumping in and out of digital spaces. These virtual experiences can impact the physical world by catalyzing both physiological and cognitive responses; virtual reality users hearts have pumped intensely while crossing a virtual pit (Blascovich & Bailenson, 2011), and viewers exposed to negative and highly arousing images, tend to forget the information presented before those negative images (Lang, Newhagen, & Reeves, 1996). Though virtual experiences can be highly engaging and attention grabbing in the moment, they appear to have impact once the experience is completed, thus it is paramount to further examine how virtual experiences influence processes (such as memory) in the physical world.

An important concept used to investigate virtual experiences is presence. Generally, presence is a subjective experience that is a psychological measure of "being there" or being in the virtual environment (Lee, 2004; Nowak & Biocca, 2003; Bailenson and Yee, 2007; Ahn & Bailenson, 2011). Presence is sometimes considered a measure of the success of a media experience, with higher levels of presence deemed as more successful (Nowak & Biocca, 2003; Meehan, Insko, Whitton, Brooks, Jr., 2002). There are three broad definitions of presence that are commonly used: physical, social, and self (Lee, 2004; Biocca, 1997). Physical presence measures how real the virtual space and the objects within it seem to users. Social presence typically refers to how virtual social actors are experienced as actual actors. Finally, self-presence measures the degree that the virtual self is experienced as the actual self.

Currently, much of the literature focuses on the impact that high presence has on attitude and behavior change or task performance (Persky & Blascovich, 2008; Skalski & Tamborini, 2007; Fox, Bailenson, & Binney, 2009). For example, a study by Skalski and Tamborini (2007) found that individuals with higher levels of perceived presence were more likely to be persuaded by health messages compared to those with low perceived presence.

Typically, memory tasks (i.e. tests of recall) have been used as a proxy for measuring presence: how much information of the virtual environment that is remembered is associated with levels of presence. In regards to this, there are two different approaches in which memory recall is used as a way to get at levels of presence. One viewpoint posits that the greater level of presence users' experience, the more specific details (e.g. virtual objects, spatial layout) and information (e.g. message content) they will remember of the virtual environment (Lin, Duh, Parker, Abi-Rached, & Furness, 2002; Mania & Chalmers, 2001). The results from a study by Dinh, Walker, Song, Kobayashi, and Hodges (1999) suggest that increased levels of sensory input (e.g. olfactory feedback) can increase the levels of overall presence (in a virtual office) and the memory of the virtual environment. Specifically, participants in the more sensory environment experienced higher levels of presence and remembered more objects /the spatial layout of the virtual office.

An opposing approach to memory and presence proposes that if a user is fully engaged in a virtual environment, he or she will remember less specific details or content (Fox, Bailenson, & Binney, 2009; Nichols, Haldane, & Wilson, 2000). Fox, Bailenson, and Binney (2009) demonstrated that participants that viewed their avatar gaining weight as it ate, consumed less candy post treatment compared to those that had an unchanging avatar. While watching their avatar in the virtual environment they were required to remember a series of numbers presented to them visually in the same virtual space. Memory was used as a manipulation check, and participants exposed to the changing avatar body (treatment group) remembered fewer numbers and reported higher levels of presence than those in the unchanging condition. The memory tasks presented in these studies, like many others, focused on recalling objects, spaces, and information presented in the virtual world. They typically used measures of physical presence. To stay consistent with memory and presence literature, the remainder of this paper will focus on physical presence.

Few studies have focused on the impact that presence within a virtual world has on memory tasks conducted in the physical world. However, some literature demonstrates that experiences in immersive virtual environments (IVEs) (technology that induces presence) can impact memory recall outside of the virtual environment. For example, one study by Segovia and Bailenson (2009) placed children into an immersive virtual reality simulation and then interviewed them after the experience. Children in the virtual reality condition reported more false memories, confusing the virtual experience as having happened in the real world earlier in their lives. This effect lasted several days after treatment. This study illustrates that the power of highly immersive and presence evoking technology can impact memory about and in the physical world. Though this study showed the impact that virtual reality may have on memory, it failed to investigate what specific mechanism (such as level of presence) that affected memory, particularly when the information in the physical world was similar to the virtual world.

Virtual reality provides multiple sensory experiences that can enhance presence (Dinh, Walker, Song, Kobayashi, & Hodges, 1999). Researchers exploring the relationship between presence and memory have suggested the utility of the technological features unique to virtual reality: "This application could be developed further, most importantly by manipulating elements related to a specific task. It could incorporate, for example stereo-displays, head tracking for navigation, more interactivity and also levels of photo-realistic rendering" (Dinh, Walker, Song, Kobayashi, & Hodges, 1999, p.261). In addition, Steuer (1992) proposes that virtual reality could be described in more than technological features, but in terms of the human experience of presence; suggesting that virtual reality experiences are intimately linked to presence.

This paper explores the impact that physical presence in a virtual environment has on memory tasks in the real world. Specifically, we investigated how items remembered in the real world are impacted by the level of physical presence previously experienced in immersive virtual reality. It was hypothesized that higher levels of physical presence would be positively associated with the number of correct items recalled on a memory task in the physical world. Findings of a preliminary study are presented as well as theoretical reasoning for the results and implications for future work.

1. Methods

1.1. Study overview

A within-subjects study design was implemented to explore the relationship between the level of physical presence (PVE) in a virtual environment and memory. Using an immersive virtual environment (IVE), participants were placed in a virtual world in which they were given a pro-environmental message on energy conservation. Once they were removed from virtual reality, participants completed a brief questionnaire measuring the level of environmental presence they experienced while in the IVE. After the questionnaire, they completed a memory task on pro-environmental principles on information related to IVE treatment.

1.2. Sample

A convenience sample was recruited from the student population of a medium-sized West Coast university in the USA. Students were offered course credit for their participation. The final sample (n= 33) consisted of seventeen women and sixteen men 18 to 22 years of age (M=18.5, SD = 1.03). At 71.0% (n=22), the majority of students were in their first year of college. The sample of students identified as 41.9% (n=13) White; 29% (n=9) Multiple races; 16.1% (n=5) Hispanic, Latino, or Spanish origin (e.g. Mexican, Puerto Rican); 9.7% (n=3) Chinese or Chinese American; 6.5% (n=2) Black, African, or African-American; 6.5% (n=2) Asian Indian; 3.2% (n=1) American Indian or Alaska Native; and. 3.2% (n=1) as Other.

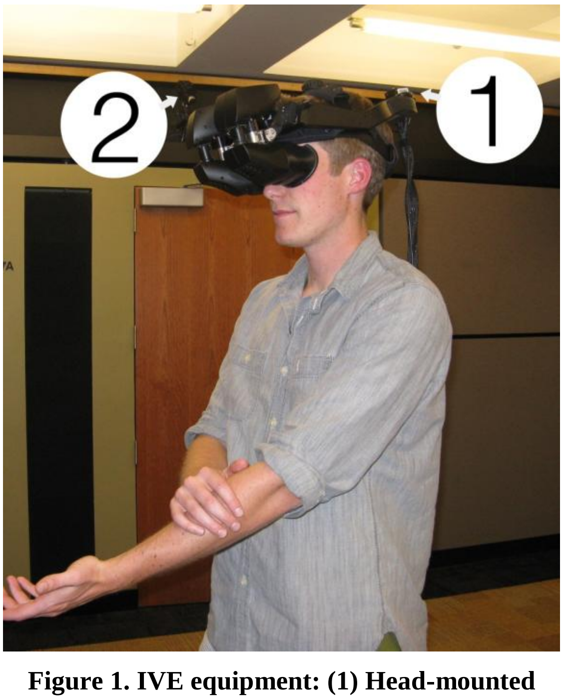

Figure 1. IVE equipment: (1) Head-mounted display, (2) Infrared cameras that track participant head movement

***Figure 2.* First person point of view of virtual shower. Participants saw feedback on how much energy was used to transport and heat water for their virtual shower.**

1.3. Apparatus

Participants wore a virtual reality headset called a head-mounted display (HMD), specifically a nVisor SX111 HMD (NVIS, Reston, VA) with a resolution of 2056 x 1024 and a refresh rate of 120 frames per second (Figure 1). The head piece contained a lens for each eye allowing for stereoscopic views of the virtual world. Orientation sensing equipment (Intersence3 Cube) tracked users' head movements in order to create a realistic depiction of the virtual environment that updated based on their motion. The virtual environment was generated and programmed using Worldviz Vizard.

1.4. Design and Procedure

Participants spent approximately 5 minutes in a virtual shower with a first person point of view in which they received real-time feedback on how much energy was being consumed to transport and heat water for their virtual shower.[1] One to two months previous to the experiment participants completed an online self-report questionnaire measuring demographic information. All participants were part of a larger study investigating the use of virtual reality to promote pro-environmental behaviors, specifically to reduce the amount of hot water used during a shower (Figure 2). Through a narrative, participants read about how much energy (i.e. coal) was used to heat and transport water for a shower in the physical world. While in the virtual world they were provided with visual feedback on how much coal was used to heat and transport water to heat their virtual shower. After the virtual shower, they completed a post-questionnaire in which the level of PVE was measured. Then an experimenter read to each participant fifteen environmental principles on ways to conserve water, each accompanied by a specific example (Appendix A). The principles were randomly ordered for each experiment. Participants then had to teach as many of the fifteen principles as they could remember to another study participant within a five minute time period.[2] Then participants were provided with two memory tasks on information related to their virtual experience. They then completed two brief written tests; a) a free recall test in which they listed as many of the principles as they could remember (specific examples excluded); and b) a cued recall test in which they were provided a list of the fifteen principles and had to fill in the accompanying example. These two different recall tasks were used to better explore how presence my impact different types of memory performance (i.e. ability of the brain to remember with or without prompt). Since both tests were provided to each participant, the information they were asked to recall was different to reduce the impact of one test on another.

1.5. Measures

1.5.1. Demographics. Participants self-reported sex, age, race/ethnicity, and year in school.

1.5.2. Free recall. The number of fifteen environment principles participants correctly wrote down without any prompting (specific water use examples excluded).

1.5.3. Cued recall. The number of correct examples of water conservation that participants could remember with prompting. They were provided a list of the fifteen principles and had to write the correct corresponding example that had been read to them previously.

1.5.4. Physical presence of virtual environment (PVE). A five-item scale measuring the subjective feeling that the virtual environment is real (in this case a virtual shower) ($\alpha = .77$). A five-item scaled was adapted from presence scales used in previous studies (Bailenson and Yee, 2007; Ahn & Bailenson, 2011; Nowak & Biocca, 2003). Questions assessed *to what extent did you feel… 1) that you were really inside the virtual shower, 2) that you were surrounded by the virtual shower, 3) that you really visited the virtual shower, 4) that the virtual shower seemed like the real world, 5) that you could reach out and touch the objects in the virtual shower*. Participants selected from the response options *not at all, slightly, moderately, strongly, and very strongly*.

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[1] Participants were part of a larger study investigating the effects of virtual reality on promoting pro-environmental behaviors. The independent variables from the larger study were statistically accounted for during the current study and were not shown to have any significant effect on the data.

[2] The participants that were taught the fifteen principles were part of a study on observing communication patterns of teaching and learning interactions.

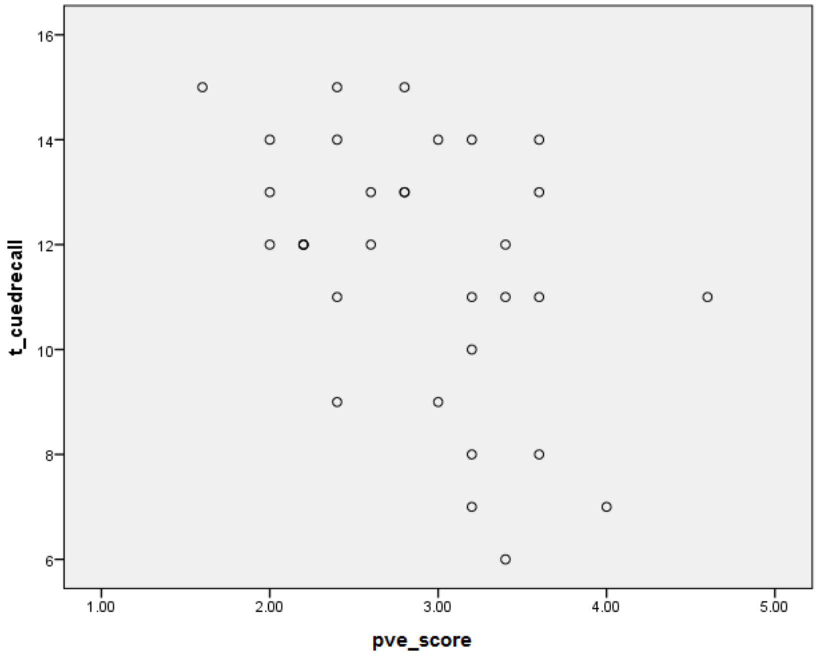

Figure 3. **Physical presence score and memory. Scatterplot displaying the negative association between participants' reported physical presence (pve_score) and the number of correct items identified through cued recall.**

An average is computed such that greater numbers indicated greater levels of presence.

2. Results

Participants reported a range of six to fifteen correct answers on both the free recall (M = 9.72, SD = 2.11) and cued recall tests (M = 11.59, SD = 2.49). A single outlier that was two standard deviations below the cued recall mean was removed. Results revealed a statistically significant negative correlation between PVE and memory. Cued recall and PVE score were significantly correlated, $r(30) = -.45$, $p<.05$ (Figure 3); such that the greater the level of physical presence in the virtual world reported, the fewer examples of the environmental principles participants remembered outside of the virtual environment. Free recall and the PVE score were also negatively correlated but not significantly, $r(30) = -.067$, $p>.05$. Both of these negative correlations were the opposite effect that was hypothesized. Table 1 displays the correlations between free recall and cued recall and the individual scale items. According to these results, the negative association between presence and cued recall is driven primarily by the extent participants felt that they "could reach out and touch objects in the virtual shower."

3. Discussion

As previous research has indicated, few studies have explicitly examined the relationship between memory and physical presence in virtual reality. Most memory tasks utilized in experiments have focused on participants recalling the spatial layouts of or objects in a virtual world. This study was a step towards understanding the impact of virtual experiences on memory performance in real world tasks. The results showed a significant negative association between physical presence and memory.

Table 1. Correlation of Environmental Presence, Free Recall, and Cued Recall

	Item							
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Felt inside virtual shower	_							
2. Felt surrounded by virtual shower	.39	_						
3. Felt visited virtual shower	.59**	.39*	_					
4. Felt virtual shower seemed like the real world	.51**	.19	.43**	_				
5. Felt could reach out and touch objects in virtual shower	.23	.23	.22	.65**	_			
6. Total PVE score	.74**	.62**	.72**	.78**	.69**	_		
7. Free recall	-.04	-.14	-.14	.09	-.01	-.07	_	
8. Cued recall	-.21	-.33	-.27	-.24	-.48**	-.45*	.53**	_

* p <.05, two-tailed. ** p <.01, two-tailed

As self-reported levels of presence increased, the fewer number of correct examples of water conservation were recalled by participants, the opposite of the expected hypothesis. The greater level of presence that participants experienced in the virtual world appears to be associated with their ability to remember certain types of information.

Though these results were not initially anticipated, they are not entirely surprising. As previously mentioned research using virtual reality has found changes in attitudes and behaviors, however not always in the expected direction (Groom, Bailenson, & Nass, 2009). Other underlying mechanisms such as limited cognitive capacity, mediated arousal, and individual differences among participants could influence outcomes. The following sections provide theoretical explanations of how high feelings of presence can negatively impact memory.

3.1. Limited cognitive capacity

The attention grabbing capabilities of IVEs may drain mental resources related to memory. Human brains have limited cognitive resources to navigate through the world, including perceiving virtual experiences. According to the Limited Capacity Model of Motivated Mediated Message Processing (LC4M), "during mediated message use, controlled and automatic mechanisms allocate processing resources continuously overtime to encoding, storage, and retrieval as a function of the structure, content, and motivational and personal relevance of the mediated message" (Lang, 2006, p. S62). According to this model, mediated experiences (i.e. highly vivid pro-environmental message) that exceed resources to process and/or are aversive will less likely be stored. For example, studies have implicated that though vivid messages can sometimes enhance learning, under certain circumstances a vivid context may hinder effects (Taylor & Wood, 1983; Keller & Block, 1997; Taylor & Thompson, 1982; Collins & Taylor, 1988; Kisielius, & Sternthal, 1984). As such, it is possible that after experiencing a highly vivid and sensory experience, participants had limited cognitive resources to dedicate to the memory task. In addition, the structural features (i.e. movement, sensory feedback) of the virtual environment may have grabbed participant's attention creating a high sense of "being there" but consequently draining cognitive energy. This may explain why participants are able to successfully recall specific details of virtual environments but struggle to remember related information outside of the virtual world.

3.2. Mediated arousal

Mediated experiences grab attention and stimulate physiological arousal (Lang, 1990). Immersive virtual environments have the capability of providing highly sensory experiences (Steuer, 1992; Biocca, 1997), and thus inducing arousal. Nass and Reeves (1996) indicate that arousal can influence cognitive processes: "arousal is intimately linked to rational thought. The separation of thinking and feeling is an illusion. It is not locked away, never to influence other parts of mental life" (p. 139). Research has shown that regardless of valence (positive or negative feeling) excessive levels of emotional arousal hinders memory. For example, in a study by Lang, Newhagen, & Reeves (1996) participants that watched a news program that contained both low and high arousing content had trouble remembering the information presented right before the highly arousing scenes. In addition, emotional arousal stimulated by media experiences recedes slowly, transferring arousal from one experience to the next (Zillman, 1983; Wirth & Schramm, 2005). Perhaps the highly sensory experience of our virtual reality treatment enhanced a feeling of presence but may have hit a threshold of arousal that hindered memory. Another possibility is that the virtual reality induced arousal transferred into the subsequent context increasing the levels of arousal during the memory task.

3.3. Individual differences

Researchers have suggested that individuals' personalities, past experiences, and mental abilities for imagination are important factors for understanding presence (Heeter, 2003; Wirth et al., 2007). One study investigating the individual differences among people found that participants that had the capacity to be highly absorbed, more creative, and more willing to be immersed in an experience, felt a greater sense of presence in virtual reality (Sas & O'Hare, 2003). Research also indicates that individual differences exist in relation to memory and cognition. Certain memory tasks, such as a free recall, require a high level of cognitive retrieval proficiency (Perlmutter, 1979) which may vary with each individual's capabilities. Research has implicated that high media multitaskers have less cognitive control and process information differently than light media multitaskers (Ophir, Nass, Wagner, 2009). Perhaps the individual differences that are important to consider for presence are somehow linked to memory. It may be the case that certain capabilities or individual difference exists such that those that experience high presence remember information differently than those that do not.

3.4. Limitations

The major limitations to this study are the use of a convenience sample and that the results are correlational, making causation and directionality unclear. However, the use of a convenience sample does bring up an interesting issue. As indicated previously, individual differences have been associated with how presence in virtual environments is experienced. Perhaps something about the make-up of the community in which the sample was drawn from influences their virtual and real world experiences. Future research would warrant better understanding the ways in which individual differences play a role in presence and memory. In addition, studies could vary the degrees of sensory input to better understand what specific elements enhance presence but hinder memory. Looking at these various elements could allow users to better understand how to utilize technology to motivate but to also remember important information learned in the real world. By doing so, timing of technology based interventions could be more effective.

3.5. Conclusion

Understanding how virtual environments impact memory has implications for learning, and behavior change. Techniques that effect attitude and behavior change use may not be as successful for teaching specific information; one may be an issue of motivation while the other a case of ability. For example, an anti-drug treatment may provide a highly sensory experience that motivates a person to stop using, but if timed incorrectly prevent them from remembering the instructions their case worker provides them in the real world. A better understanding of presence on memory could inform the development of educational and behavioral treatments in virtual environments. How humans process the physical world may be more related to the virtual than most would consider.

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Appendix A

Instructions and the fifteen environmental principles read to participants

I'm going to explain fifteen environmental principles related to water and energy use to you, and then I'm going to ask you to teach as many as you remember to a new participant in a few minutes. I'll give a principle, and then an example of one kind of change in behavior that would illustrate this principle. First, I will explain these to you verbally. Next, I will bring in your student, and you may teach the principles to them verbally in any way that you like. You will have five minutes to do so.

1. Stop water from leaking. Fixing a dripping faucet would be a good example of a way to save both water and unnecessary expense.
2. Do not use more water than is necessary for a given task. For example, turn off the water in the shower, instead of allowing it to run while shampooing.
3. Minimize your use of *hot* water. For example, washing clothes in warm or cold water instead of hot can save energy.
4. Reuse water whenever possible. For example, keep a bucket in the shower and use the water to water plants.
5. Avoid using water entirely when other methods are possible. For example, don't use a power-washer or hose to clean your porch off when you can sweep instead.
6. Adjust your water use to the weather. For example, it's often against city regulations to water your lawn when it is hot out, because water will evaporate quickly and it's wastefully ineffective.
7. Be careful not to pollute natural waterways, since this is water that may need to be used again. For example, do not pour motor oil directly into drains or sewers, because this may pollute groundwater.
8. Avoid using products that require a lot of water to produce. For example, a lot of water is used in raising animals for meat. Therefore, reducing one's meat consumption is a good way to save water.
9. Keep track of your water use. If you monitor the volume of water you are using, you can be more careful about conservation. For example, you could use a timer while you are in the shower in order to be mindful about the amount of water you are using.
10. Turn off appliances that use or heat water when you don't need them. For example, if you are leaving town for a vacation, it is a good idea to turn off your hot water heater while you are gone, since otherwise you will be wasting energy keeping water hot for no-one to use.
11. Heat water in the most energy efficient way. You want to make sure that as much as possible of the energy you use is going directly to heating the water that you want to use, and only that water. For example, when heating water for a hot drink, it is more energy efficient to heat water in an electric kettle instead of a microwave.
12. Use economy settings on appliances. Many modern appliances have energy or water-sparing settings. For example, dishwashers can be set to

use less water or less hot water by simply pressing a button.

13. Patronize businesses that use water/energy in efficient ways. Not only does this save water in itself, but it also encourages other businesses to follow eco-friendly practices. For example, if you must take your car to a car wash, then go to one that recycles its wash water.

14. Plan ahead to avoid having to use or heat water unnecessarily. For example, instead of running hot water on frozen food to thaw it, defrost items overnight in the refrigerator.

15. Do not use bottled water. In this country tap water is safe to drink, so using bottled water is wastes energy both in packaging and transport. Bringing your own reusable water bottle with you is a great way to save energy.