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Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior

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ABSTRACT

Immersive virtual environments (IVEs) allow individuals to see, hear, and feel digital stimuli as if they were in the physical world. Two studies tested the power of embodied experiences within IVEs by comparing the effects of cutting a virtual tree against reading a print description or watching a video depiction of the tree-cutting process to encourage paper conservation. Experiment 1 found that IVEs led participants to consume 20% less paper than participants who read a print description of tree cutting. Experiment 2 demonstrated that IVEs elicited greater self-reported internal environmental locus of control and self-reported environmental behaviors than print and video messages one week following the virtual experience. Moreover, internal environmental locus of control served as a mediator, driving environmental behaviors. We discuss the implications of using embodied experiences for behavior change.

1. Introduction

A recent review of nearly 12,000 peer-reviewed papers in the climate science literature found that 97% of the academic discourse attributed human-related causes to the rising gravity of climate change and global warming (Cook et al., 2013; Marlon, Leiserowitz, & Feinberg, 2013). On the other hand, the same problem is construed differently in the minds of the American public, with only 41% of them attributing climate change to human-related causes (Leiserowitz et al., 2013). This attribution gap may partly explain the general lack of behavior change despite the abundance of information regarding environmental problems (Kollmuss & Agyeman, 2002). Scholars further recognize that while a strong communication strategy is crucial in motivating environmental behaviors, ignorance about the science behind climate change is not what is preventing greater concern and action (Moser & Dilling, 2010). Providing more information and explanation has not and most likely will not solve this problem.

A number of surveys have already explored critical factors that lead to environmental behaviors. Among findings is that attitudinal variables, in particular, environmental *locus of control* (Cleveland, Kalamas, & Laroche, 2005), are strong predictors of environmental behaviors. The perception that one's behaviors directly impact the wellbeing of the environment—an internal locus of control—seems to be one of the most powerful drivers of environmental behaviors (Allen & Ferrand, 1999). If an internal locus of control for environmental problems could be heightened among individuals that consider their own actions to be irrelevant to climate change problems, the attribution gap discussed earlier may decrease significantly.

Despite the abundance of survey research that connects an internal environmental locus of control to increased environmental behaviors (Allen & Ferrand, 1999; Bamberg & Möser, 2007; Cleveland et al., 2005; Curtis, 1984), there is a dearth in experimental manipulations of locus of control to promote environmental behaviors. The following set of experiments aims to fill this gap in the literature with preliminary investigations of immersive virtual environments as vehicles of change in the context of environmental behaviors. In particular, the effect of interactive and perceptually rich experiences within immersive virtual environments was compared against the effect of traditional print and video messages. Furthermore, locus of control was assessed immediately after and one week after experimental treatments as a possible underlying mechanism driving environmental behaviors.

2. Environmental locus of control

The concept of locus of control was first proposed by Rotter (1960) as the extent that individuals internally attribute the cause

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of events. Internal locus of control promotes the belief that outcomes may be directly influenced by individual actions, rather than uncontrollable external influences. Consequently, it is likely to elicit the perception that modifying one's behaviors may lead to desired outcomes, and thus, serve as motivation for the individual to change his or her behavior.

Surveys in the field of environmental psychology have repeatedly found that an internal locus of control is one of the strongest predictors of environmental behaviors (Allen & Ferrand, 1999; Bamberg & Möser, 2007; Cleveland et al., 2005; Curtis, 1984). When individuals feel that their individual behaviors directly influence the wellbeing of the environment, they are more likely to be concerned about and actively care for the environment. A meta-analysis reviewing psycho-social determinants of environmental behavior also confirmed that such perception of personal control is one of the strongest predictors of environmental behaviors, along with behavioral intentions (Bamberg & Möser, 2007).

As the original locus of control scale is an assessment of a general perception of control over life events, scales for measuring perceived locus of control specifically in the context of environmental behaviors have also been developed and successfully validated (Cleveland et al., 2005; Smith-Sebasto & Fortner, 1994). Given these insights, the solution to increasing environmental behaviors seems deceptively simple—heighten the perception of internal locus of control for environmental problems; thereafter, environmental behaviors are likely to ensue.

However, the gap between what people know about environmental problems and what they decide to do about it still runs wide and deep (Kollmuss & Agyeman, 2002; Newton & Meyer, 2013). In analyzing why the issue of global warming fails to alarm the public to take action, Weber (2006) noted, "The time-delayed, abstract, and often statistical nature of the risks of global warming does not evoke strong visceral reactions" (p. 1). Because environmental problems often occur in a macro (rather than a micro) context, wherein entire societies are affected rather than a single individual, and because of the temporal gap between individual actions (e.g., failing to recycle paper) and their negative consequences on the environment (e.g., deforestation), the risk of environmental problems may seem distant and outside of one's control to most people. This poses a challenge in promoting an internal locus of control and, as a result, a challenge in promoting environmental behaviors.

3. The power of experience

A growing collection of empirical data from the science of decision-making may yield insights into resolving the time-delayed, abstract, and often distant nature of environmental problems. Recently, a number of scholars have discovered that similar information can lead to different choices depending on whether it was acquired through personal experience or through print description (Hertwing, Barron, Weber, & Erev, 2004; Marx et al., 2007; Weber, 2006). This was found to be particularly true for low-probability events: unless the low-probability event happened in the very recent past, individuals are likely to underweight the risk of the event (Hertwing et al., 2004).

Because the probability of personally experiencing an environmental problem is relatively low compared to other everyday events, the overall risk perception of environmental problems is also likely to be low. However, when individuals thought that they had personally experienced the negative consequences of environmental problems such as global warming, studies have shown that they considered environmental problems to be significantly more personally relevant than those that had not personally experienced negative consequences (Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013). Hence, Weber (2006) prescribes that scholars should find ways to evoke visceral reactions toward the risk of environmental problems, perhaps via simulations of concrete future consequences.

If personal experience of negative consequences increases the personal relevancy of the problem, having individuals actively engage in, as well as perceptually experience, the negative consequence would heighten their internal locus of control, emphasizing the fact that their individual actions may directly impact the environment. However, having individuals actually produce negative consequences in nature and cause environmental damage, so that they may later learn to protect it, is obviously counterproductive. Thus, a realistic simulation that allows individuals to actively engage in and experience concrete negative consequences, yet has little to no actual consequences to the physical environment would be an optimal solution.

3.1. Embodied experiences in virtual environments

Immersive virtual environments (IVEs), digital devices that offer rich layers of perceptual information in a simulated environment (Blascovich & Bailenson, 2011), may serve as one potential solution. Using IVEs, users may see, hear, and feel negative future consequences of their present actions as if they were occurring in the moment. For example, individuals may viscerally experience their contribution toward deforestation as a result of failing to conserve and recycle paper by experiencing a simulation of cutting down a virtual tree wherein they would actively engage in cutting the tree. This would effectively reduce the temporal distance between the cause (individual behavior) and the effect (negative consequences to the environment) as individuals would be able to experience a future negative consequence as if it were occurring in the moment. In addition, actively cutting down a virtual tree would promote the perception that individual behaviors may directly impact environmental outcomes, heightening an internal locus of control.

Earlier studies have attested to the power of the realism of embodied experiences in IVEs and their influences on behavioral modification in several ways. First, the individual is able to experience vivid perceptual information by entering the virtual world in the first person perspective, seeing, hearing, and feeling as if he or she were in the physical world. In one study, when individuals were given the ability to view the world through a color filter, wherein they experienced the virtual world as a red-green colorblind person, they spent twice as much extra time and effort to help an unfamiliar colorblind person in the physical world compared to individuals that only heard a description about the experience (Ahn, Le, & Bailenson, 2013). Similarly, another study showed that when individuals felt a higher sense of realism looking around in a 3-dimensional reproduction of a university campus, it led to a greater perception of overall locus of control (Murray, Fox, & Pettifer, 2007). In the context of environmental awareness, individuals that experienced a simulated flood in an IVE showed increased emergency preparedness compared to those that merely viewed a slideshow of a flood (Zaalberg & Midden, 2010). Furthermore, a related series of studies have demonstrated that experiencing interactive feedback from digital media channels, including energy meters on household appliances (McCalley & Midden, 2002) and robots offering social interactions, led to more favorable energy-consumption behaviors (Ham & Midden, 2014).

Other studies have looked at embodied experiences through the use of virtual representations controlled by the user (i.e., avatars). These studies demonstrated that after experiencing the IVE world as avatars, users modified their behaviors in the physical world in a variety of ways, including increasing their physical activity and becoming more confident in interpersonal interactions

(Fox & Bailenson, 2009; Yee, Bailenson, & Ducheneaut, 2009). In those studies, experiences while embodying the avatar in the virtual world transferred into the physical world to influence behavior.

Yet another factor of IVEs that contribute to realistic experiences is its high interactivity. Interactivity is not a novel concept and has been defined in different ways; in the current experiments, it is defined as an attribute of technology—an affordance that provides real-time feedback to the user (Sims, 1997; Sundar, 2004)—rather than perceived interactivity which may vary drastically from one user to another even when using the same device. Under this definition, the affordance of traditional media, such as print or video, to provide an interactive experience would be significantly lower than that of an IVE, which offers real-time tracking and rendering of movements as well as the ability to touch and move objects in the virtual world.

Taken together, the concrete and interactive experience of a negative consequence (i.e., cutting down a virtual tree) within the IVE would be more realistic compared to a description of the consequence, leading to the recognition that an individual's action is directly related to the wellbeing of the environment—an internal environmental locus of control (**H1**). Following earlier findings that connect higher internal locus of control to environmental behaviors (Allen & Ferrand, 1999; Bamberg & Möser, 2007; Cleveland et al., 2005; Curtis, 1984), we predicted that the embodied experience of cutting down a virtual tree in the IVE would lead to more environmental behavior (i.e., less paper consumption) than a description of the tree-cutting (**H2**).

3.2. Individual differences in perceived embodiment

In addition, individual differences in responding to virtually mediated experiences were considered. In particular, the tendency and willingness to share another person's experiences has been found to moderate responses within virtual experiences. Studies have shown that individuals with high tendencies to take another person's perspective experienced high levels of realism in a virtual simulation (Sas & O'Hare, 2003; Wallach, Safir, & Samana, 2009). The ability to take the perspective of others has also been closely linked with concern for environmental issues (Schultz, 2000); individuals who are able to take the perspective of the nature and its inhabitants are more concerned about environmental issues and therefore more likely to engage in environmental behaviors. The Perspective Taking Propensity scale (PTP; Gehlbach, Brinkworth, & Wang, 2012) is a measure of such tendencies to take the perspective of others and will be used in the current study (Experiment 1) to control for individual differences in response to embodying environmental experiences in IVEs.

A number of studies also point to sex/gender differences in the perception of virtual environments. For instance, males and females focus on different cues while navigating in virtual environments (Sandstrom, Kaufman, & Huettel, 1998) and perceive realism of virtual content in different ways (Lombard & Ditton, 1997). To this extent, the variable sex will also be controlled for to account for sex-related differences in perceptions during embodied experiences in IVEs.

4. Experiment 1

The current study compared the effect of embodied experiences in an IVE against a print description of the experience on environmental behavior. The environmental issue depicted the negative consequence of deforestation as a result of failing to recycle paper products. Before the experiment, a pilot test was conducted with a separate group of participants to develop a print stimulus with comparable content to the IVE stimulus of cutting down a virtual tree as an embodied experience of deforestation.

4.1. Pilot study

Fourteen undergraduate participants (7 female, 7 male) were recruited to develop the print stimulus. The participants were asked to experience the IVE condition and to describe it in detail. Two methods were combined to capture as much of the participants' descriptions of the IVE experience as possible. First, participants were asked to describe every sensory detail in the virtual forest aloud. These real-time thoughts were recorded with an audio device and later transcribed. Secondly, after the participants finished cutting the virtual tree down, they were subject to a thought-listing procedure (Cacioppo & Petty, 1981), which asked participants to write down all of their thoughts during the virtual experience. Based on the information from transcribed audio files and the thought-listing procedure, a stimulus that included all of the verbal information gathered from all fourteen participants was developed for the print condition.

4.2. Methods

4.2.1. Participants

The sample ($N = 47$) consisted of 29 women and 18 men aged 18–46 ($M = 21.60$, $SD = 4.27$) from a medium-sized West Coast university in the United States.

4.2.2. Apparatus

A head mounted display (HMD; NVIS SX111), a goggle with a monitor (640 horizontal by 512 vertical pixel resolution) for each eye, was used to allow participants to see the virtual forest in three-dimension. Wearing the HMD, participants were able to look around the IVE with naturalistic head movements as if they were in the physical world. Spatialized audio information was provided through earphones ensuring that participants received realistic sounds of the forest. The computer was also equipped with a force-feedback haptic joystick (Sensable Phantom Omni) that allowed users to interact in real time with objects in the IVE. Using the joystick, participants were able to control the chain saw used to cut down the virtual tree with backward and forward sawing movements. Participants were also able to feel realistic resistance and vibrations as they worked the saw through the tree trunk. Fig. 1 depicts the experimental setup.

4.2.3. Procedure

The experiment was conducted in two phases. One week before the experiment, all participants received an online pretest that measured baseline levels of environmental locus of control and perspective-taking propensity. Approximately one week later, participants arrived at the laboratory. The researcher read out loud some background information on paper consumption and how it leads to deforestation while the participants read along (Appendix A). Participants were then randomly assigned to either the IVE or the print condition.

Participants in the IVE condition ($n = 24$) put on the HMD and entered the virtual world in the first-person perspective, standing in front of a large tree holding the handle of a chain saw. Before engaging in any cutting activities, participants were asked to look around the forest, taking note of details such as the sound of the birds chirping and the trees surrounding them. Participants then heard and felt the chain saw start, and were instructed to begin moving the haptic joystick back and forth to cut the tree down. The movement of the joystick in the physical world was synced to the movement of the virtual arms moving the chain saw. The program required all participants to engage in cutting motions for two minutes. After two minutes, participants saw and heard the tree trunk crash down to the ground and were asked to look around the forest once more. As a result of cutting the tree, the

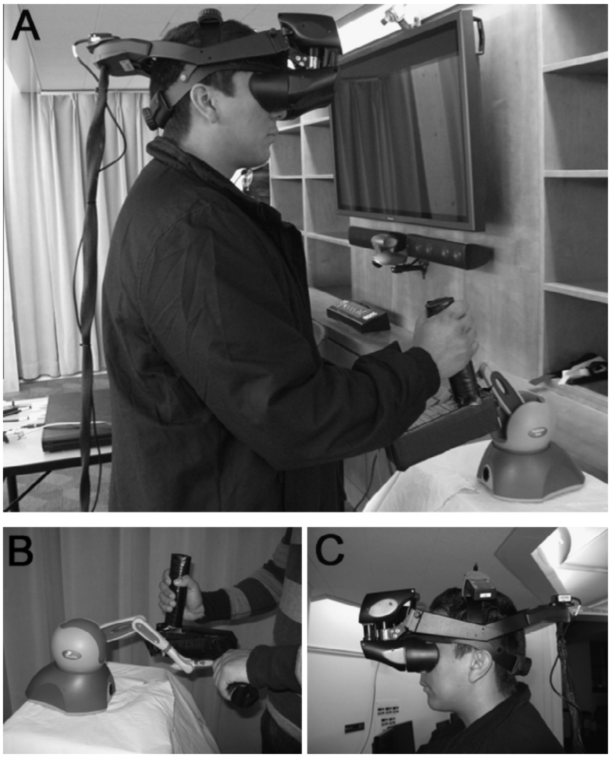

Fig. 1. Experimental setup for the IVE condition (A). Participants wore a head-mounted display (C) and were able to look around the virtual forest in stereovision and heard spatialized aural inputs wearing headphones (headphones not shown). The head-mounted display (C) was equipped with an orientation device that allowed head-controlled point of view in the IVE. They were then instructed to pull and push the force-feedback haptic joystick (B) to cut the virtual tree down.

forest was programmed to become completely quiet and all movement was removed to emphasize the damage inflicted upon the forest. Participants were then guided toward a computer where they filled out a questionnaire. Fig. 2 depicts the series of events in the virtual forest.

In the print condition ($n = 23$), participants were asked to create a vivid picture in their minds about what they might see, hear, and feel in the forest while reading the detailed print stimulus developed from the pilot test that depicted the forest, the tree-cutting process, and the silent forest after the tree fell down. When they finished reading, participants were guided to a computer where they filled out a questionnaire.

In order to allow for some time to pass after the experimental treatment so that the immediate sensitization toward environmental issues would wear off, participants were asked to participate in a 30-min long additional experiment that was irrelevant to the first one. Upon completion of this irrelevant experiment, a veiled measure of environmental behavior was administered.

4.2.4. Dependent measures

4.2.4.1. Environmental locus of control. This was measured as a baseline and again immediately following experimental treatments to capture the effect of respective treatments on environmental locus of control. Ten items from the Environmental Action Internal Control Index (Smith-Sebasto & Fortner, 1994) assessed participants' perception of an internal locus of control with regard to environmental issues. Participants answered on a 5-point interval scale (1 = *Does not describe my point of view well*; 5 = *Describes my point of view very well*) the extent to which they agreed to statements that describe how individual actions can improve the environment (e.g., ''My individual actions would improve the quality of the environment if I were to buy and use recycled paper products''). Reliability for this measure was high with Cronbach's $\alpha = .94$ for the pretest measure and Cronbach's $\alpha = .96$ for the posttest measure.

4.2.4.2. Environmental behavior. Participants were seated at a table for the veiled behavioral measure. Before each participant entered the laboratory, all preparations for this measure were systematically calibrated so that each participant would be exposed to the same procedure each time. First, approximately 2 fluid ounces of water were pre-measured using the same cup each time. A pre-counted stack of napkins was prepared and inconspicuously placed in another corner of the room so that the participants would not become suspicious of the situation. Participants were asked to fill out a demographic information sheet at the table. During this process the experimenter approached the table and knocked over the cup of water, ostensibly by mistake. The experimenter then asked each participant for help by saying, ''I'm so sorry, but I have to prepare the next participant for the experiment. Could you help me clean the water up?'' and handed the pre-counted number of napkins to the participant. After the participant left, the number of used napkins was counted as an inverse measure of environmental behavior.

4.2.4.3. Perspective Taking Propensity (PTP – covariate). Seven items from Gehlbach's Social Perspective Taking Propensity Scale (Gehlbach et al. 2012) assessed each individual's disposition to try to take the perspective of another person. Participants were asked to indicate on a 5-point interval scale (1 = *Almost never*; 5 = *Almost all the time*) how often they attempted to understand and try to put themselves in the shoes of another (e.g., ''Overall, how often do you try to understand the point of view of other people?). Reliability for all seven items was Cronbach's $\alpha = .88$ and the items were averaged to create a comprehensive PTP score. The exact wording of the questionnaire items can be found in Appendix B.

4.3. Results

All assumptions for an Analysis of Covariance (ANCOVA) were met. Homogeneity of the regression effect was evident for the covariates and they were linearly related to at least one dependent variable. Descriptive statistics for all dependent variables can be viewed in Table 1.

4.3.1. Environmental locus of control

A repeated-measures ANCOVA was conducted with experimental condition as the between-subjects variable, the pretest and posttest measures of environmental locus of control as the within-subjects variable, and PTP and sex as covariates, to assess the change between levels of environmental locus of control before and after experimental treatments. The difference in pre- and posttest locus of control was significant after controlling for PTP and sex, $F(1, 41) = 7.19$, $p = .01$, partial $\eta^2 = .15$. As Table 1 demonstrates, both IVE and print conditions were successful in significantly increasing participants' belief that their individual actions could make meaningful changes to the environment. No other effects in the model were significant. H1 was not supported.

4.3.2. Environmental behavior

To test H2, an ANCOVA was conducted with experimental condition as the independent variable, the number of napkins used as the dependent variable, and PTP and sex as covariates. The main effect of experimental condition was significant after controlling for PTP and sex, $F(1, 47) = 4.42$, $p = .04$, partial $\eta^2 = .09$.[3] Means

[3] This main effect of experimental condition is not significant without controlling for the covariates.

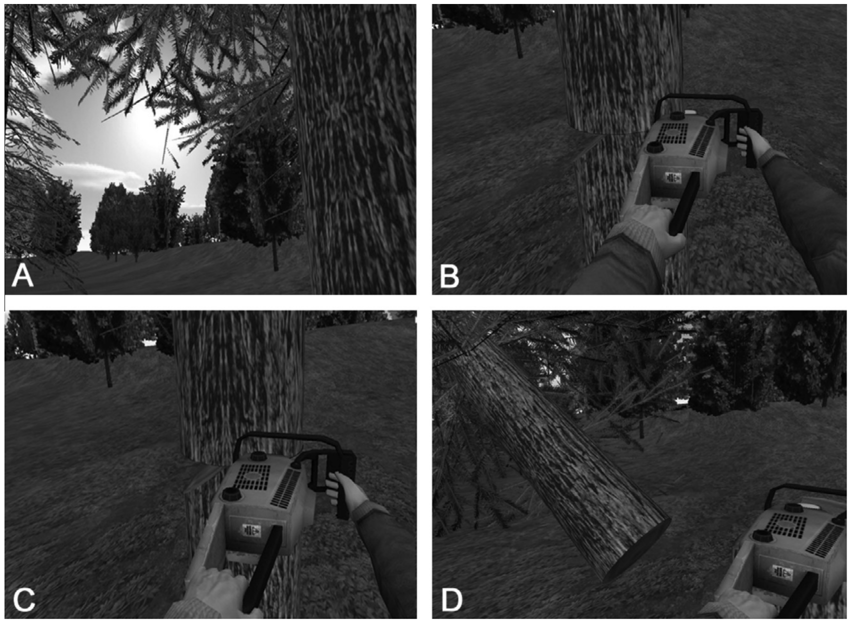

Fig. 2. Screenshot of the series of events in the IVE condition. Participants saw the virtual forest in first-person perspective (A). They used a chain saw to cut the large tree in front of them (B). Participants moved the chain saw for two minutes with the joystick (C) until the tree crashed to the ground (D).

Table 1
Descriptive statistics for dependent measures in Experiment 1 ($N = 47$).

	IVE	Print
Napkins	4.61(2.35)	5.61(2.43)
Pre-locus of control	3.01(1.00)	3.24(.99)
Post-locus of control	3.38(1.01)	3.70(.93)

demonstrated that participants in the IVE condition used significantly fewer napkins compared to participants in the print condition. PTP was not a significant covariate but sex had a p-value of .08 and a partial η^2 value of .07. H2 was supported.

4.4. Discussion

Results of Experiment 1 demonstrated the potential of using IVEs to promote environmental behaviors: the personal experience of a future negative consequence—cutting a virtual tree—was sufficiently powerful to encourage individuals to use approximately 20% fewer paper napkins in the physical world compared to individuals who merely read a description about cutting a tree. These results imply that IVEs are more effective than traditional print messages in closing the knowledge-to-action gap and promoting conservation behavior.

However, no difference was found between the two conditions in promoting an internal environmental locus of control, and a follow-up experiment was conducted to further explore the underlying process driving the behavioral change found here. Because video is another popular traditional medium for delivering environmental communication, Experiment 2 compared IVE against both print and video. Moreover, delayed effects of IVE exposure were tracked after one week's time following the experimental treatments.

5. Experiment 2

To address the shortcomings of the first experiment, the scope of Experiment 2 was expanded in several ways. First, video was included as another traditional platform for environmental communication in addition to print as earlier research has indicated the effectiveness of video-based messages, particularly with the advent of social networking media (Paek, Hove, Jeong, & Kim, 2011). IVE and video are comparable in that they are both predominantly nonverbal media, but IVE augments visual, aural, and tactile perceptual information to deliver interactive embodied experiences whereas the monoscopic, two-dimensional contents in video are viewed passively. Because IVEs offer a richer array of sensory information as well as greater interactivity with the mediated environment compared to video, they lead to greater perceptions of realism (Persky & Blascovich, 2008). Furthermore, higher perceptions of realism during embodied experiences in IVEs has been shown to lead to greater behavioral change compared to mere descriptions of the same context (Ahn et al., 2013). Thus, IVEs are expected to be more effective in promoting an internal environmental locus of control (**H3A**) and, as a result, greater environmental behaviors than print and video (**H3B**).

On the other hand, results from prior research comparing the effects of print and video are mixed. Some studies have found that video and print messages perform just as well in educating patients about a health condition immediately following and one week after exposure to the message (Wilson et al., 2010). Similar findings confirmed no difference in the recall of information presented via print versus video (Campbell, Goldman, Boccia, & Skinner, 2004). A recent literature review also reported that the majority of studies comparing print to multimedia materials in patient education found that video and print messages show no difference in effectiveness (Wilson et al., 2012). Conversely, Pfau, Holbert, Zubric, and Lin (2000) argued that print and video trigger different mental processes in response to persuasion attempts and that one is not necessarily more effective than the other. Other researchers have also found that the addition of pictures and graphics to print material serves to enhance memory for print news (Griffin & Stevenson, 1992). Thus, it is not clear how print environmental messages will compare to video environmental messages in terms of the promotion of environmental locus of control and environmental behaviors and this was explored as a research question (**RQ1**).

Secondly, although prior surveys (Allen & Ferrand, 1999; Bamberg & Möser, 2007; Cleveland et al., 2005; Curtis, 1984) suggested significant correlations between environmental locus of control and environmental behaviors, few, if any, studies have explored the role of environmental locus of control as a mediating variable driving environmental behaviors. It is likely that the medium that offers personal experiences of negative future consequences leads to higher internal environmental locus of control (H3A), and the heightened internal environmental locus of control, in turn, serves as a mediator driving environmental behavior (**H4**).

Thirdly, the question of the duration of effects is particularly relevant as the ultimate goal of promoting environmental behaviors is to have the behaviors persist over time. In other words, treatments effects that decay rapidly outside of the laboratory might not be as socially relevant. IVEs are inherently much more interactive compared to traditional media (Blascovich & Bailenson, 2011) and studies demonstrate that interactive features encourage greater elaboration and involvement with the message (Skalski & Tamborini, 2007). In turn, the Elaboration Likelihood Model (Petty & Cacioppo, 1986) suggests that greater elaboration of a message typically produces longer lasting persuasion and attitude change. Thus, to compare the longer-term effects of embodied experiences against traditional media effects, the data were collected once immediately after and again one week after exposure to the experimental stimuli and analyzed over this one week period.

Finally, a number of studies have demonstrated that the level of awareness that an individual has about the consequences of an action motivates him or her to engage in prosocial behavior (Nordlund & Garvill, 2002) and more specifically in environmental behavior (Bamberg & Möser, 2007). Based on these findings, individual differences in the awareness of consequences of excessive paper consumption was measured and controlled for in the ensuing analyses in place of sex and perspective-taking propensity as a more context-relevant covariate.

5.1. Methods

5.1.1. Participants

A sample was obtained from a public university in the Southern United States. A total of 65 participants initially volunteered to take part in the study and five participants dropped out during the one week period. The final sample ($N = 60$) consisted of 45 women and 15 men aged 18–24 ($M = 20.32$, SD = 1.16).

5.1.2. Procedure

The experimental setup was identical to that used in Experiment 1, but different models of IVE equipment were used (HMD: VR2000 Pro Dual, 1024 by 768 pixel resolution; Novint Falcon haptic joystick). Experiment 2 was conducted in two phases. At Time 1, participants came to the laboratory and received the background information on paper consumption and deforestation from Experiment 1. Participants were then randomly assigned to print, video, or IVE conditions. Participants in the print condition ($n = 20$) and the IVE condition ($n = 21$) experienced the same experimental stimuli from Experiment 1. Participants in the video condition ($n = 19$) saw a video depiction of the tree-cutting process that was approximately two minutes long on a desktop monitor. This video closely mimicked the IVE simulation by showing a first person viewpoint of the tree-cutting process using a chainsaw. As in the IVE condition, the video ended after the tree was completely cut, its trunk crashing to the ground. Contrary to the IVE condition, participants in the video condition were unable to view the clip in three-dimensional depth, hear the tree-cutting process with stereo audio, actively look around in the world, or control the chainsaw. Upon completion of the experimental treatment, participants were taken to a separate survey room to complete questionnaires about their experience. One week following the experimental stimuli at Time 1, participants received email instructions to complete the delayed posttest (Time 2) online. In order to make a direct comparison between the measures taken at Times 1 and 2, and due to the difficulty of repeating the covert behavioral measure (i.e., napkin use) without raising suspicion, environmental behavioral intention and environmental behavior were assessed via self-report at both times (Appendix B).

5.1.3. Dependent measures

5.1.3.1. Environmental behavioral intention. The specific context of recycling was selected for measurement so that participants would have a clearer understanding of environmental behaviors. Three 5-point interval scale items gauged participants' intent to engage in recycling-relevant behaviors at Time 1: recycling paper products, purchasing recycled paper products, and using recycled paper products. Reliability for the three items was Cronbach's $\alpha = .68$.

5.1.3.2. Environmental behavior. Three 5-point interval scale items gauged participants' success in recycling-relevant behaviors at Time 2, during the week following exposure to the experimental treatments—recycling paper products, purchasing recycled paper products, and using recycled paper products. Reliability was Cronbach's $\alpha = .67$.

5.1.3.3. Environmental locus of control. The same 5-point interval scale from Experiment 1 was used to assess two internal locus of control items related to recycling-relevant behaviors—reusing or recycling paper items, and purchasing and using recycled paper products. Reliability for the two items was Cronbach's $\alpha = .82$ at Time 1 and Cronbach's $\alpha = .89$ for Time 2.

5.1.3.4. Awareness of consequences (covariate). Two 5-point interval scale items gauged the extent to which participants were aware of the consequences of failure to recycle paper products (i.e., failing to recycling paper products causes a greater number of landfills) and to purchase and use recycled paper products (i.e., failing to use recycled paper products will result in more trees being cut down to produce virgin pulp). Reliability for the two items was moderate, Cronbach's $\alpha = .76$.

5.2. Results

All assumptions for an Analysis of Covariance (ANCOVA) were met. Awareness of consequences was highly correlated with all dependent variables at Times 1 and 2 (all $ps < .01$). Descriptive statistics for the dependent variables are presented in Table 2.

5.2.1. Environmental locus of control

A repeated measures ANCOVA was conducted with Time as a within-subjects factor, environmental locus of control measured at Times 1 and 2 as the within-subjects variables, experimental condition as the independent variable, and awareness of consequence as the covariate. The within-subjects effects were not significant, but the main effect of experimental condition averaged across Times 1 and 2 was significant, $F(1, 56) = 4.43$, $p = .01$, partial $\eta^2 = .14$. Post-hoc analyses using Fisher's LSD indicated that IVEs led to significantly higher internal environmental locus of control

Table 2
Descriptive statistics for dependent measures in Experiment 2 ($N = 60$).

	Video	Print	IVE
Locus of control (Time 1)	3.74(.54)	3.69(.98)	3.96(.92)
Locus of control (Time 2)	3.40(1.09)	3.80(.80)	4.17(.94)
Behavioral intent (Time 1)	3.48(.68)	3.39(.70)	3.71(.71)
Behavior (Time 2)	2.63(.84)	2.46(.80)	3.03(.75)

compared to video ($p = .005$; 95% CI lower = .157, upper = .838), and marginally higher compared to text ($p = .06$; 95% CI lower = −.032, upper = 659). No other pairwise comparisons were significant. Thus, H3A was supported.

5.2.1.1. Environmental behavior. A repeated measures ANCOVA was conducted with Time as a within-subjects factor, environmental behavioral intentions measured at Time 1 and environmental behavior measured at Time 2 as the within-subjects variables, experimental condition as the independent variable, and the same covariate. The within-subjects effects were not significant, but the main effect of experimental condition averaged across Times 1 and 2 was significant, $F(1, 56) = 3.47$, $p = .04$, partial $\eta^2 = .11$. Post-hoc analyses using Fisher's LSD indicated that IVEs led to significantly higher environmental behavior compared to print ($p = .01$; 95% CI lower = .092, upper = .754) and marginally significant compared to video ($p = .08$; 95% CI lower = −.037, upper = .625). No other pairwise comparisons were significant. Thus, H3B was supported.

5.2.1.2. Mediation analyses. To test the validity of the mediation model, the PROCESS path-analysis macro for SPSS (Hayes, 2012) was used to test the mediation model at Times 1 and 2. Based on the findings from the series of ANCOVAs, print and video were grouped as traditional media (dummy = 0) and compared against IVEs (dummy = 1). First, the experimental conditions were entered as the independent variable, environmental locus of control measured at Time 1 as the mediator, and environmental behavioral intention as the dependent variable. Awareness of consequences was entered as a control variable. Bootstrapping methods were used. A second mediation analysis was conducted with the same independent variable, environmental locus of control measured at Time 2 as the mediator, and environmental behavior as the dependent variable. Results of the direct and indirect effects are reported in Table 3.

As the lower and upper limits of the confidence interval includes zero, no mediation was found at Time 1. However, results confirmed that an internal environmental locus of control successfully mediated environmental behaviors one week following experimental treatments at Time 2. IVEs led to greater internal environmental locus of control compared to traditional media, and greater internal environmental locus of control, in turn, led to greater environmental behavior compared to traditional media. Thus, H4 was supported at Time 2 but not at Time 1.

5.3. Discussion

These results yielded further insight into the underlying mechanisms driving the behavior change observed in Experiment 1. Means and statistical tests demonstrated that during the week following the experimental stimuli, the effect of reading and seeing consequences of excessive paper consumption through print and video diminished whereas the effect of embodying the experience of cutting down a tree in an IVE remained relatively stable over time, controlling for individual differences in the awareness of consequences. Furthermore, environmental locus of control mediated the relationship between experimental conditions and environmental behavior at Time 2. Summative analyses of Experiments 1 and 2 are discussed below.

6. General discussion

6.1. Summary of findings

Experiment 1 compared the embodied experience of cutting down a virtual tree in an IVE against a print description of cutting down a tree on environmental behavior. When informed that deforestation is a negative consequence of excessive paper consumption, participants who embodied the experience of cutting down a virtual tree used 20% less napkins compared to participants who read a print description about the tree cutting. However, both IVEs and the print description led to a significant increase in internal environmental locus of control immediately following experimental treatments.

Experiment 2 expanded the scope of investigation on several dimensions by exploring environmental locus of control as the driver of environmental behavioral intentions and behaviors. Because video messages are also often used to deliver environmental messages, a video depiction of the tree-cutting process was included as an experimental treatment compared against IVEs. Results confirmed interesting changes one week following experimental treatments. The effect of print and video on environmental locus of control and behavior declined over the course of one week whereas

Table 3
Regression weights, indirect effects showing mediation, bootstrap 95% confidence interval, lower and upper bounds.

	Coefficient	*SE*	Bootstrap 95% CI Lower	Bootstrap 95% CI Upper
Time 1				
Direct effects				
Condition → locus of control	.12	.23	−.328	.577
Condition → behavioral intention	.11	.16	−.216	.445
Locus of control → behavioral intention**	.41	.10	.214	.597
Indirect Effects	Effect Size	*Bootstrap SE*		
Condition → locus of control → behavioral intention	.05	.10	−.127	.290
	Coefficient	*SE*	Bootstrap 95% CI Lower	Bootstrap 95% CI Upper
Time 2				
Direct effects				
Condition → locus of control**	.57	.21	.152	.983
Condition → behavior	.32	.19	−.070	.705
Locus of control → behavior*	.22	.12	−.014	.451
Indirect effects	Effect Size	*Bootstrap SE*		
Condition → locus of control → behavior*	.12	.08	.011	.349

Notes: *SE* = standard error; CI = confidence interval.
Bootstrap resampling = 1000.
** $p < .01$.
* $p < .05$.

the effects of IVEs persisted relatively strongly. The effect of IVEs on environmental locus of control and behavior was consistently stronger than print and video, whereas the effects between print and video were not significantly different across all measures at Time 2. Mediation analysis confirmed that an internal locus of control for environmental issues (conserving paper) mediated the relationship between experimental conditions and environmental behaviors, not immediately after, but one week after experimental treatments.

6.2. Contributions to behavioral research

The current studies contribute to theories of behavioral change (Ajzen, 1991; Bandura, 1977) in the context of environmental behaviors as one of the few studies to experimentally manipulate environmental locus of control. These results extend the findings from earlier survey research on the correlations between environmental locus of control and environmental behavior (Allen & Ferrand, 1999; Bamberg & Möser, 2007; Cleveland et al., 2005; Curtis, 1984) in several ways. First, these experiments demonstrated that an internal environmental locus of control might be manipulated experimentally by allowing individuals to experience perceptually rich and interactive simulations of future negative consequences. This presents new avenues of research on the environmental locus of control, such as the investigation of messaging strategies to maximize an internal, rather than an external, locus of control.

In addition, an internal environmental locus of control mediated the relationship between visceral experiences in IVEs and environmental behaviors, but only after some time had passed following experimental treatments. The findings suggest that this may be because the effects of print and video dissipate over time whereas the effects of the IVE experience persist. It has been suggested that salient memories lead to a greater likelihood of behavioral change (Ajzen, 1991). One possible explanation may be that the interactive experience of cutting down a tree, wherein the participant actively engaged in cutting motions with the haptick joystick, encouraged the participant to think that there was a direct relationship between his or her behaviors and the wellbeing of the environment. This active engagement in the negative experience, in addition to the rich layers of perceptual information during the experience, may have helped the memory of the IVE experience to remain more salient throughout the week leading to greater environmental behaviors compared to print or video messages.

Another possible explanation may be derived from the propositions of other persuasion scholars who posited that increased elaboration of a message increases the persistence of behavioral change over time (Petty & Cacioppo, 1986). Because IVEs allow users to embody rich layers of sensory information as if he or she were undergoing the experience in the real world, they are by nature more interactive than print or video. As interactivity in low and high immersive virtual environments has been shown to lead to increased elaboration and involvement (Ahn & Bailenson, 2011; Skalski & Tamborini, 2007), it is likely that participants in the IVE condition may have elaborated further about paper consumption and its consequences. Greater elaboration and involvement with the message, in turn, is likely to have assisted in the persistence of environmental behaviors over time.

The current results also echo earlier findings from decision-making research that demonstrate the power of personal experiences over print descriptions (Hogarth & Soyer, 2011; Marx et al., 2007; Weber, 2006) and expand the comparison to include video depictions of events. In these earlier studies, personal experience of a low probability event was often simulated with card games involving inconsequential amounts of cash rewards. IVEs allow users to experience visceral simulations that involve substantial consequences that were not possible in traditional laboratory settings, expanding these earlier findings to contexts that are more applicable to highly consequential real-life risks. Future studies should compare the effects of simulations that involve consequences of varying degrees to explore the effect that the gravity of the consequence has on behavior change.

Finally, results from the two experiments also yield some insight into measurement issues in behavioral research. The objective measure of environmental behavior in Experiment 1 (i.e., napkin use) was able to detect significant differences between IVEs and print immediately following experimental treatments, and the same veiled measure has successfully assessed environmental behavior elsewhere (Ahn, Fox, Dale, & Avant, in press). However, the self-reports used in Experiment 2 did not detect differences between experimental treatments until one week afterwards. It may be that self-reports are less sensitive in assessing behavior changes immediately following experimental treatments compared to objective measures. Earlier studies using IVEs have also found that self-report measures may not be sensitive enough to detect immediate effects of IVE exposure (Bailenson et al., 2004). Thus, the current experiments suggest that future behavioral research incorporating IVEs should incorporate both subjective and objective measures of behavior to compliment each other.

6.3. Contributions to IVE research

These experiments are one of the first attempts to use IVEs to influence environmental behaviors, while comparing the advanced digital medium against more traditional verbal (print) and nonverbal (video) media. This is also one of the few studies that reported actual changes in environmental behavior that transferred from the virtual to the physical world in the context of "green" behavior. By demonstrating that embodied experiences in IVEs led to 20% less paper consumption in the physical world and greater self-reported environmental behavior one week following exposure, the current study makes a meaningful contribution to the growing literature that demonstrates the potential of IVE messages as vehicles of prosocial behaviors (Ahn, in press; Fox & Bailenson, 2009). In assessing the prosocial capacity of emerging digital media, Amichai-Hamburger and Hayat (2011) have discussed the Internet's ability to improve the psychological well being of users. Through embodied experiences, IVEs may serve to extend these prosocial boundaries to improve the well being of the overall environment that the users reside in.

The results also provide an empirical response to the question of IVEs' advantage over video. Earlier studies have demonstrated that even with the same message, different channels and cues used to deliver the message may vary its effectiveness (McLuhan, 1964; Trevino, Lengel, & Daft, 1987). Video visualized the content of the print message but it was a passive source of medium whereas IVEs allowed individuals to actively interact with and embody the message. Earlier scholars have defined richness of a medium by its capacities for immediate feedback, number of available cues, language variety, and personal relevance (Trevino et al., 1987). Indeed, the current results imply that the affordances of the medium that allows users to viscerally experience and interact with the mediated content may lead to greater behavioral changes compared to simple visualization.

Results also extend the results of the few studies that directly compare the effect of print and video by confirming no significant differences between print and video descriptions on the promotion of internal environmental locus of control as well as environmental behaviors. This echoes earlier findings that also show no differences between the effects of print and video on patient education (Wilson et al., 2010) and information recall (Campbell et al., 2004). Sundar's study (2000) on online news media also found that although adding static pictures to a print message amplified its effect on a variety of measures including recall, credibility, and coherence, adding a video component to the print message led to no difference or fared worse compared to viewing just the print message. Thus, taken together, it is suggested that behavioral modification for low-probability, high-risk events is most effective when using IVEs to deliver visceral simulations. However, when considering the development of a video message to promote behavior, print messages may serve just as well at a fraction of the cost.

6.4. Limitations and future research

The results from the current experiments are qualified by some limitations. In an actual public campaign designed to promote environmental behaviors, audiences are often repeatedly exposed to messages from different media platforms at once. Although the fact that we observed significant changes in environmental locus of control and behaviors from a single exposure is encouraging, effects of repeated exposures to IVE experiences and how they persist over time is an interesting topic for future research. Another limitation that restricts the generalizability of the current experiments is the fact that the participants were selected based on a convenience sample of undergraduate and graduate students. This limits the representativeness of the current sample in terms of demographic variables such as age, income, and education, and may threaten the external validity of the experiment (Kruglanski, 1975). Future research should test the effect of IVE based messages on a wide range of representative samples.

Also, most real world environmental messages present specific action plans in order to facilitate behavioral modification (Bator & Cialdini, 2000). The current experiments focused on comparing distilled experimental stimuli for experimental control—a visceral IVE simulation against print and video descriptions of tree-cutting following a priming manipulation—but did not use realistic environmental messages promoting specific action plans. Future research should test whether including a specific goal or an action plan in the message better promotes behavioral modification compared to more generic environmental messages that lack a specific goal.

Finally, prior literature on time perspective suggests that individuals have inherent differences in the ability to cognitively represent the future in their minds (Zimbardo & Boyd, 1999), and a meta-analysis on engagement with environmental issues confirmed that those more adept at considering future consequences are more likely to care about the environment (Milfront, Wilson, & Diniz, 2012). Offering IVE-based experiences may be helpful for individuals who are lower in this spectrum of ability by presenting a vivid experience of the future. Future studies should assess future time perspectives as a trait to control for individual differences.

6.5. Conclusion

With the advent of consumer level IVE devices, we are now able to experience highly immersive and highly interactive media in the comforts of our own living room. For instance, gamers use actual physical movements to control their avatars with Microsoft's Kinect system. Also, the joystick used for the current experiment is already a widely used device among gamers. High quality HMDs, such as the Oculus Rift, are being produced for the masses at a price point lower than that of commonly used mobile phones. IVE technology is becoming light, affordable, and accessible to the public. As a result of this increasing ubiquity of the hardware and the software among general consumers, the future holds much promise for using IVEs to develop and disseminate messages to promote environmental behaviors. We hope this experiment is indicative of these exciting potentials and will instigate active future research of IVEs as a powerful persuasion tool that can shape and modify a wide range of desirable behaviors.

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Appendix A

On average, each person consumes 50.71 lb of toilet paper a year in North America. This is more than 12 lb over the world average of 38.4 lb. Because 98% of toilet paper sold in the United States comes from virgin wood, this means that about 42,000 trees are cut down each day to fulfill the demand for non-recycled toilet paper. Consequently, 32.12 acres of global forests are lost annually, 14.82 acres of which are primary-forests – the most biologically diverse ecological systems in the world.

The following is some more information on toilet paper usage and tree-cutting. An average American uses about 23.6 rolls of toilet paper per year. Because a single tree produces roughly 1000 rolls of toilet paper, that means a large tree is cut down every 42 years to supply the average American with non-recycled toilet paper.

If you are twenty years old, you have already cut down half of a tree during your lifetime because you chose to use non-recycled toilet paper.

Appendix B

B.1. Perspective taking propensity

Please read the following statements carefully, and rate the extent to how well these statements describe you (*1 = Almost never; 2 = Once in a while; 3 = Sometimes; 4 = Frequently; 5 = Almost all the time*).

1. How often do you attempt to understand your friends better by trying to figure out what they are thinking?
2. How often do you try to think of more than one explanation for why someone else acted as they did?
3. Overall, how often do you try to understand the point of view of other people?
4. When you are angry at someone, how often do you try to "put yourself in his or her shoes"?
5. How often do you try to figure out what motivates others to behave as they do?
6. How often do you try to figure out what emotions people are feeling when you meet them for the first time?
7. In general, how often do you try to understand how other people view the situation?

B.2. Pre-treatment self-efficacy

Please read the following statements and indicate how well does each statement describes your point of view (*1 = Does not describe my point of view well; 2 = Describes my point of view slightly well; 3 = Describes my point of view moderately well; 4 = Describes my point of view pretty well; 5 = Describes my point of view extremely well*).

1. My individual actions would improve the quality of the environment if I were to carpool instead of driving alone.

2. My individual actions would improve the quality of the environment if I were to set my home appliances, such as the refrigerator, dishwasher, water heater, etc. to "energy-saver" levels.
3. My individual actions would improve the quality of the environment if I were to learn about the recycling facilities in my area.
4. My individual actions would improve the quality of the environment if I were to attend a community meeting that involves concern over a local environmental issue.
5. My individual actions would improve the quality of the environment if I were to buy resource conservation devices, such as low-flow faucet aerators for my sinks and low-flow shower heads.
6. My individual actions would improve the quality of the environment if I were to open windows for ventilation rather than using a fan or air conditioner.
7. My individual actions would improve the quality of the environment if I were to buy products packaged in containers that either can be reused or recycled or are made of recycled materials.
8. My individual actions would improve the quality of the environment if I were to reduce the amount of my household trash by reusing or recycling items to the fullest extent possible.
9. My individual actions would improve the quality of the environment if I were to take my old tires to a recycling center.
10. My individual actions would improve the quality of the environment if I were to buy and use recycled paper products.

B.3. Environmental behavioral intention

After you walk out of this room, please indicate the extent to which you plan to take the following actions (*1 = Never; 2 = Rarely; 3 = Sometimes; 4 = Quite Often; 5 = Very Often*).

1. How often will you recycle paper products?
2. How often will you purchase a product because it is packaged in reusable or recyclable paper?
3. How likely is it that you will switch from your current brand of toilet paper to use a recycled brand (even if the recycled brand might be lesser in quality)?

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