# Persuasive Effects of Immersion in Virtual Environments for Measuring Pro-Environmental Behaviors

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**Abstract –**

**In this study, we investigated the effects of immersive vs. non-immersive virtual environment (VE) platforms (i.e., head mounted display (HMD) vs. laptop PC) on compliance with pro-environmental behaviors. We performed a detailed analysis of the effects of these VE platforms on other variables, such as task performance, sense of presence, and simulator sickness. We also explored the factors, such as participants' gender and immersive tendency that could have influenced the effects of VE platforms. In a between subject design, 100 participants were randomly assigned to interact with either a desktop or an HMD. The results showed no significant effects of VE platforms on compliance with pro-environmental requests, task performance, and sense of presence. However, the HMD elicited higher simulator sickness compared to the desktop display. In addition, we demonstrated there was a strong relationship between participants' immersive tendency and the presence that they experienced. Our findings provide empirical evidence capable of helping researchers select an appropriate VE platform when investigating the influence of behavioral interventions aim to promote sustainable behaviors.**

**Keywords –**

**Virtual environments; pro-environmental behavior; immersion; presence; simulator sickness; compliance**

## 1 Introduction

To study occupant behavior in general and occupants' interactions with buildings, many studies used immersive virtual environments to collect occupant-related data [1-3]. For example, Heydarian et al. used immersive virtual environments to collect data on occupants' lighting-related behaviors and preference. They used the data to investigate the design alternatives aiming to meet occupants lighting preferences while increasing building's energy efficiency [2]. Saeidi et al. investigated the effectiveness of IVEs to be used as a tool to collect data on occupant behavior. They suggested that IVEs can be more valuable tools if they are used during the design stage of the building to define the main drivers of occupants' lighting behaviors in buildings [4]. Virtual environments (VEs) are also increasingly used for scientifically studying the effects of communication in different persuasive contexts (e.g., health, advertising, and education) on human behavior by enhancing the experimental designs in a controlled manner [5-7]. However, the VE systems that have been used across different studies vary in their dimensions specifically in their level of immersion, the degree to which a system can "deliver an extensive, inclusive, surrounding, and vivid illusion of virtual environment to a user [8]." Immersion is one of the main factors required to enable the users to perceive all aspects of the space to create lifelike impression [9]. Choice of an appropriate system for a specific application impacts the effectiveness of VEs [10]. VEs are mostly characterized based on their platforms (e.g., desktop/laptop PC, head mounted display (HMD), etc.). However, there is no guideline leading us to the selection of an appropriate platform. One of the main considerations in the selection of appropriate VE platform is the level of immersion, which is often linked to the sense of presence and simulator sickness (motion sickness experienced during an interaction with a VE) experienced by users of those environments. "Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another [11]."

Studies have used different VE platforms varying from a simple desktop/laptop computer with standard monitors to more immersive environments like HMD, in which users wear the computer display on their head to be immersed, and later to a fully immersive environment, like Cave Automatic Virtual Environment (CAVE), in which users move around in a room where they are completely surrounded with computer projected displays.

Each platform has different characteristics and user interfaces. Selection of the VE platform could impact the behavioral responses of participants engaging with the VEs [5]. However, it is relatively unclear whether the level of immersion, sense of presence, and simulator sickness experienced through different VE platforms influence user performance and behavior. Often, the effects of VE platforms on performance and behavior appear to be overshadowed by other factors, such as task context and user characteristics (e.g., age, gender, and previous experience with VEs) [12,13].

Several studies have been completed to investigate this issue and compared various platforms with each other in different contexts. In this study, we investigated the influence of VE platforms on measuring compliance with pro-environmental requests. We compared a non-immersive VE (i.e., laptop PC) with an immersive VE platform (i.e., HMD). To explore the factors that could influence the effects of VE platforms, we conducted an experiment, in which we investigated the effects of sense of presence and simulator sickness on user experience while interacting with different VE platforms: a laptop computer with a standard monitor and a laptop computer with a head mounted display system (laptop PC vs. HMD) and the effects of these factors on compliance with pro-environmental requests and task performance. In addition, we examined other factors, including users' gender, immersive tendency, and previous experience with VEs that could impact the effects of VE platforms on compliance. Immersive tendency refers to individual differences in the proclivity to become immersed in a simulation and previous experience with VE, like playing video games, can influence the immersive tendency [11].

## 2 Background

A common assumption about virtual environments is that increased immersion is associated with higher experienced presence and it results in enhanced task performance and behavior change. However, research shows that there are conflicting views on whether the level of immersion impacts the user's experienced presence, performance, and behavior. For example, Gorini et al. [14] tested the effects of a VE platform (immersive vs. non-immersive) and narrative context (emotional vs. non-emotional) on the users' experienced presence. Their results suggested that both immersion and context have a significant role in generating an effective VR experience as they contribute to increasing the feeling of presence from different aspects. In another study, Grassi et al. [15] investigated the effects of different platforms (mobile phone, desktop PC, and HMD) as well as emotional context (amusement, sadness, fear, and neutral) on the sense of presence and the results showed that platform type did not impact the sense of presence while the emotional context did impact the sense of presence.

User characteristics (e.g., gender, immersive tendency, and previous experience with VEs) can also influence sense of presence. Sense of presence and performance in VEs is likely to increase when user is familiar with the VEs and has higher immersive tendency. However, other studies found no relationship between sense of presence and immersive tendency and VE experience. A study conducted by Nowak et al. [16], investigating causes and consequences of presence in the context of violent video games, showed that user's characteristics (previous game experience and gender) can predict presence. In another study, Schuemie et al. [17] exposed participants to a virtual environment for phobia treatment and they found no correlation between sense of presence and gender or experience with VEs. These findings suggest that a user's sense of presence in a VE might not be influenced only by the characteristics of the VR platform; but also by context of the task performed and the characteristics of the individual user (e.g., gender and previous experience with VEs) [18].

A review of the relationship between the level of immersion and performance in VEs revealed that a positive relationship exists between the level of immersion and behavioral responses and performance. For example, Kim et al. [5] investigated whether different VE platforms (desktop PC, HMD, and CAVE) induce different patterns of emotional responses in contexts including high- and low-stress tasks. The results of their study suggested that immersive virtual environments (either an HMD or fully immersive VE platform) were more effective than a standard desktop PC in eliciting emotional arousal.

Simulator sickness might also influence user's experience of VEs. For example, Kim et al. [5] investigated the effects of different VE platforms (desktop, HMD, and CAVE) on simulator sickness while completing stressful tasks. The results showed that HMD induced significantly more simulator sickness than the CAVE and the desktop.

In summary, the level of immersion in different VE platforms could influence the sense of presence and simulator sickness symptoms and might also impact user behavior and performance. However, these effects might be mediated by the context of the task and user characteristics.

Previous studies mostly focused on performance measures in contexts that involve navigation or visualization and behavioral responses in psychological settings. Less has been done to investigate behavioral responses in social contexts, in which people interact with each other to influence each other's behaviors and attitudes. In this study, we investigated whether different VE platforms with different levels of immersion elicit different behavioral responses to persuasive pro-environmental requests.

## 3 Present study

We conducted an experiment to examine the compliance with persuasive pro-environmental requests and performance, using an office related task across two representative VE platforms, which varied in their level of immersion but used the same technology to interact with the environment (an Xbox controller). As the VE platform with lower level of immersion, we used a standard laptop. As the VE platform with higher level of immersion, we used Oculus DK2 Head-Mounted Display to provide an immersive environment, in which a positional tracker would track the participants' head and neck movements (Figure 1). The virtual environment represented a single occupancy office space and was identical in both the desktop and HMD conditions.

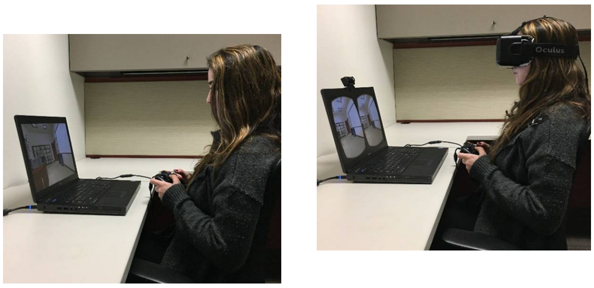

Figure 1 – Different VE platforms: laptop display (left); HMD (right)

We investigated the following dependent variables: (a) compliance with the pro-environmental request, (b) task performance, (c) presence, and (d) simulator sickness. Considering that research shows contradictory findings regarding the influence of the level of immersion as a characteristic of VE platforms on the sense of presence, behavior change, and performance, and these effects have not been investigated before in social contexts that aim to influence behavior, we could not hypothesize whether different VE platforms would generate different levels of presence or influence the compliance with the persuasive pro-environmental requests or task performance in the context of our study. Therefore, we investigated the following questions: (1) Do different VE platforms (desktop vs. HMD) influence the compliance with pro-environmental requests? (2) Do different VE platforms (desktop vs. HMD) influence the presence experienced by the participants during the experiment? (3) Do different VE platforms (desktop vs. HMD) influence the performance on the assigned task (reading a passage and answering some questions about it)? Considering that user characteristics can be another factor that influence the sense of presence, we also investigated the following questions: (4) Do different VE platforms influence the simulator sickness participants experienced while interacting with the environment? and 5) Do participants' characteristics (immersive tendency, previous VE experience, and gender) influence the presence that they experienced during the experiment? We also investigated the interaction between the sense of presence and effects of VE platform type on compliance with pro-environmental behaviors, as well as the task performance. The same for the interaction between simulator sickness and effects of VE platform type on compliance with the pro-environmental behavior and task performance.

### 3.1 Design

Pro-environmental requests included contents requesting participants to change the light level and temperature setpoint using the principles of reciprocation, which is a social influence method. A female avatar, representing the building manager, delivered the request since the adopted social influence method and delivery style were found to be among the most effective ones [19,20]. Participants were randomly assigned to one of the two experimental groups: laptop group, in which participants interacted with VE using a standard laptop without an HMD, and the HMD group, in which participants were immersed in a VE using an HMD. The only difference between these two groups was the platforms used for interacting with the VE.

### 3.2 Virtual Office Environment

The model was first generated in Revit© and then exported to 3D Max© to add materials, furniture, texture, lighting, reflection, and shadows in order to make it look more photo realistic. Then it was imported to Unity© game engine to program interactive options, such as opening/closing windows and turning on/off lights (Figure 2).

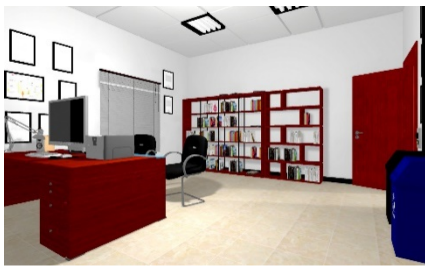

Figure 2 – Virtual Office

### 3.3 Procedure

As the first step of the experiment, participants were asked to complete a questionnaire covering general questions, including their age, gender, immersive tendency and previous experience with VE, and simulator sickness symptoms.

The Immersive Tendency Questionnaire (ITQ) was developed by Witmer and Singer [11] to measure the tendency or capabilities of individuals to be involved or immersed in a virtual environment. Simulator Sickness Questionnaire (SSQ) was developed by Kennedy et al [21] to measure the level of simulator sickness symptoms in a VE system. Prior to the main VE task, participants underwent training to become familiar with the virtual environments in which we showed them how to work with VE platforms and different settings in the virtual environment.

After the training session, we explained the experiment procedure to the participants. The procedure was as following: participants had to sit on a chair in an office and perform a very common office related activity: reading a document (two passages in this study). They were asked to read the passages very carefully as they had to answer comprehension questions about them. During the experiment, a female avatar representing the building manager would communicate with them (Figure 3).

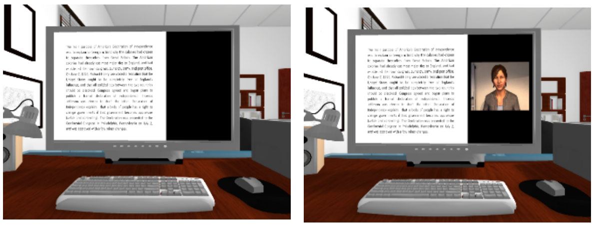

Figure 3 – Pro-environmental requests delivered to the participant in the VE

Participants were told to pay attention to the requests carefully, as they would be asked what the requests were at the end of the experiment. However, it was noted that it was completely up to the participants whether to comply or not with the requests, and that they had to act as they would in their own offices. While participants were reading the passages, a request was delivered to them (30 seconds after starting the task). Two different pro-environmental requests were delivered to each participant: (1) "if I open the blinds for you to have natural light, would you please dim or turn off the artificial lights?"; and (2) "if I open the window for you to have a breeze and fresh air, would you please increase the temperature setting on the thermostat?"

The default lighting setting in the office room was the artificial lights on while the blind was closed and the default temperature setpoint was 73˚F. If the participants chose to comply with the pro-environmental request, they had to go to the light switch and lower the level of lights or turn them off while the blind was open. Likewise, if the participants chose to comply with the other pro-environmental request, they had to go to thermostat and increase the temperature setpoint. We observed the participants' compliance with the requests in the assigned conditions (laptop vs. HMD). In addition, we assessed the participants' performance by measuring the time that they spent on reading each passage and their reading comprehension (number of correctly answered questions).

After completing the virtual part of the experiment, the participants completed the post-experiment questionnaires. The first questionnaire assessed how participant's values and attitudes resembled the environmentalists' values and attitudes. The second questionnaire assessed the participants' environmental setpoint preferences: preferences for lighting sources (daylighting vs. artificial lighting), lighting levels (amount of lighting), and temperature setpoint. As the last set of questionnaires, the participants completed two questionnaires investigating their sense of presence in the VEs: the Witmer and Singer Presence Questionnaire (PQ) [11] which measures the degree of presence and engagement that individuals experience in a virtual environment and the Slater, Usoh and Steed Presence Questionnaire [22], which focused mainly on psychological and behavioral response to immersion and involvement. Finally, participants completed the Simulator Sickness Questionnaire (SSQ). The participants had also completed the SSQ in the pre-experiment session so that their pre- and post-test scores could be compared to identify simulator sickness caused by interacting with VEs. The entire experiment took about 40 minutes.

## 4 Results

The results presented here are based on 100 participants (66 females and 34 males) recruited through the USC psychology subject pool who received course credits for their participation.

In order to analyze the data, we compared the compliance and other dependent measures including presence, task performance, and simulator sickness between the two types of VE platforms. We also investigated the effects of other factors, such as participants' characteristics (i.e., gender and immersive tendency), on the dependent measures.

To examine the effect of the VE platforms on compliance with pro-environmental requests, we conducted an independent sample T-test (laptop PC vs. HMD) on the number of times participants chose to comply with the pro-environmental requests. There were no significant differences in the number of times that participants complied with the request in the laptop PC ($M = 1.30$, $SD = .81$) and HMD ($M = 1.20$, $SD = .83$)

conditions: t(98) = .61 , p = .54. These results suggested that the level of immersion does not influence the participants' decision regarding compliance with the pro-environmental request. We also checked the possible factors that might have impacted the compliance including participants' preferred source of lighting, preferred lighting level and temperature setpoint, and identification with environmentalists. Using linear regression analysis, the results showed no main effects of these factors on compliance: preferred source of lighting ($\beta$ = -.05, $p$ = .61), preferred lighting level ($\beta$ = -.04, $p$ = .67), preferred temperature setpoint ($\beta$ = .01, $p$ = .89), and identification with environmentalists ($\beta$ = -.11, $p$ = .26).

We also investigated the influence of VE platforms on task performance. As a measure of task performance, we computed the average time to read the passages in two different conditions (laptop PC vs. HMD). Using an independent sample T-test, the results showed that there were no significant differences in the average time that the participants spent reading the passages in the laptop PC (M = 57.97, SD = 15.63) and HMD (M = 60.04, SD = 17.86) conditions: t(98) = .53 , $p$ = .25. In addition, we measured participants' reading comprehension by computing the number of correct answers to the questions that were asked about the passages. The results showed no significant difference in participants' reading comprehension in the laptop PC (M = 7.76, SD = 1.33) and HMD (M = 7.58, SD = 1.37) conditions: t(98) = .81, $p$ = .51, suggesting that participants performed in the same way in both conditions.

We examined the sense of presence using the two presence questionnaires. Investigating the effects of VE platforms on presence using the questionnaire developed by Witmer and Singer, conducting independent sample T-test, the results showed no significant difference in the sense of presence experienced in the laptop PC (M = 89.10, SD = 15.25) and HMD (M = 91.90, SD = 18.22) conditions: t(98) = -.83 , $p$ = .41. In analyzing the data from the Slater-Usoh- Steed Presence Questionnaire, using linear regression analysis, the results showed no significant difference in sense of presence experienced by different VE platforms: $\beta$ = .14, $p$ = .15.

Next, we investigated the interaction between the VE platforms and sense of presence (using the Witmer and Singer's questionnaire) by linear regression analysis. The results showed no interaction between the laptop PC (0) vs. HMD (1) dummy-coded variable and sense of presence measuring compliance ($\beta$ = -.40, $p$ = .56) and performance, both average time completion ($\beta$ = .21, $p$ = .75) and reading comprehension ($\beta$ = .18, $p$ = .79). The same results were observed for Slater-Usoh- Steed Presence Questionnaire: no interaction between VE platform and sense of presence measuring compliance ($\beta$ = -.51, $p$ = .15) and performance, both average time completion ($\beta$ = .24, $p$ = .51) and reading comprehension ($\beta$ = -.29, $p$ = .41).

Results of a mixed ANOVA on participants' simulator sickness symptoms before and after exposure to VE as well as within subjects effect and platform type and between subjects effects revealed significant interaction effects for simulator sickness (pre vs. post participation) and VE platform type (F(1, 98) = 8.24, $p$ = .005). Accordingly, we conducted independent samples T-tests to examine the effect of VE platform type on participants' level of simulator sickness both before and after the experiment. The results showed no significant differences in the participants' level of simulator sickness before the experiment in both laptop PC (M = 154.32, SD =149.63) and HMD (M = 166.81, SD = 187.44) conditions: t(98) = -.37 , $p$ = .71. However, there was a significant difference when comparing the participants' levels of simulator sickness after the experiment, such that participants experienced greater motion sickness in the HMD condition (M = 1073.89, SD = 276.56) than the laptop PC condition (M = 974.76, SD =198.59), t(98) = -2.06 , $p$ = .04. We also investigated the interaction effects of VE platform type and simulator sickness on compliance and performance. The results of analysis showed that the interaction of VE platform type and simulator sickness did not have any significant effects on compliance with pro-environmental requests ($\beta$ = -.12, p = .81) and performance, both average reading time ($\beta$ = -.84, $p$ = .1) and reading comprehension ($\beta$ = -.29, $p$ = .56).

We used the immersive tendency questionnaire to investigate if participants' characteristics influenced the sense of presence they experienced in VEs. We also tested the two experimental groups to ensure that there was not failure of random assignment (i.e., there were no significant differences between conditions in participants' levels of immersive tendency). Using independent sample T-tests, the results showed no significant differences between participants immersive tendency in the laptop PC (M = 67.62, SD = 10.54) and HMD (M = 69.76, SD = 11.40) conditions: t(98) = -.97 , $p$ = .33.

Next, we examined if the participants' immersive tendency influenced the presence they experienced in the VE, as well as their performance and compliance with the pro-environmental requests using linear regression and correlation analyses. We used the presence data collected by the Witmer and Singer's presence questionnaire as this presence questionnaire as well as the immersive tendency questionnaire were both developed by Witmer and Singer. The results showed significant effects of immersive tendency on the sense of presence, meaning that participants with higher level of immersive tendency experienced higher sense of presence ($\beta$ = .26, $p$ = .01). A person, who is more likely to become immersed in a VE, will experience a greater sense of presence while interacting with a VE. These results suggested that participants, who had the ability to get deeply involved in an activity or a stimulus, such as books or movies showing a tendency to maintain focus on that activity, were more likely to experience higher presence in the virtual environment; participants' tendency to play video games was not an effective factor causing sense of presence.

The effects of immersive tendency on the sense of presence were independent of the platform type and no significant interaction effects were found for platform type and immersive tendency ($\beta$ = .5, $p$ = .38). No significant effects were found for immersive tendency on compliance with pro-environmental request ($\beta$ = .09, $p$ = .66) and performance: average time ($\beta$= .08, $p$ = .45) and reading comprehension ($\beta$ = -.06, $p$ = .52). Also no significant effects were found for the interaction of platform type and immersive tendency on the compliance with pro-environmental request ($\beta$ = -.30, $p$ = .66) and performance, both average time ($\beta$ = -.53, $p$ = .43) and reading comprehension ($\beta$= -.94, $p$ = .16).

In addition, we used regression analyses to examine whether the participants' gender had any effects on compliance, presence, and performance or moderated impacts of VE platforms. There were no interaction effects of gender and VE platforms on compliance, presence, and performance (Table 1).

Table 1 – Gender main effects and interaction effects with VE platforms on compliance, presence, and performance

| Dependent Measure | Between Subject Measure | Beta | t |
|---|---|---|---|
| Compliance | Gender (Interaction with platform type) | .20 | .32 |
| Presence (Witmer and Singer ) | | -.20 | .33 |
| Presence (Slater-Usoh- Steed) | | -.06 | .76 |
| Performance (Average Reading Time) | | -.01 | .97 |
| Performance (Reading Comprehension) | | .20 | .31 |

Note. †$p$< .1;*$p$< .05;**$p$< .01; ***$p$ < .001

## 5 Discussion and Conclusions

Overall, the results of this study showed no significant differences in the participants' sense of presence and performance while interacting with two different VE platforms that varied in their level of immersion. In addition, there was no significant difference in participants' compliance rates in the laptop PC and HMD conditions. We also investigated the relationship between the occurrence of simulator sickness symptoms and VE platforms, compliance, and task performance. Results of our study showed HMD-based VE induced a higher level of simulator sickness. These results suggest that studies designed with the aim of minimizing simulator sickness symptoms may take advantage of using a laptop PC over an HMD [5].

We also found no relationship between participants' gender and their sense of presence, behavior and performance. In addition, we found no relationship between participants' immersive tendency and their behavior and performance. On the other hand, the results showed that there was a strong relationship between participants' immersive tendency and the presence they experienced. The participants with higher immersive tendency experienced higher sense of presence, however, these effects were independent of the type of VE platforms. We also found that individuals' tendency to become involved in situations and maintain focus on current activities can predict the presence that they experience in the VE and their previous gaming experience is not an influential factor.

This study provides findings about possible benefits and limitations of using immersive and non-immersive VE systems in a study examining the effectiveness of persuasive requests. However, there are limitations. For example, we only used two kinds of VE platforms. Although a laptop and a HMD are appropriate representations of non-immersive and immersive VE technologies, different types of VE platforms (e.g., fully immersive virtual environments like CAVE) can be addressed in future studies to continue to characterize the effects of these different VE systems on user behaviors. We plan to conduct future studies investigating the advantages and disadvantages of using different VE platforms in research on behavior change replicating and extending the findings using other behavioral contexts in buildings, such as security and comfort. Our study can also guide similar studies by comparing the effectiveness of different VE platforms and by investigating the potential factors that impact the effectiveness of these platforms.

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