Impact of Immersive Technology Applied in Computer Graphics Learning

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Abstract. *In this paper we describe an application of immersive technology to a specific learning context. In this case, a Virtual Reality environment was created for the purpose of delivering lesson content in a Computer Graphics module for students of engineering and architecture courses. The virtual environment was designed to demonstrate lighting model algorithms and aspects of 3D rendering techniques. An experiment was carried out in which students were divided into two groups that viewed the same lesson content: experimental and control group. In this pilot study we describe the application in details and discuss preliminary results based on analysis of the participants perceptions collected through presence questionnaire. Our results revealed that the experimental group showed higher levels of presence and involvement compared with the control group.*

1. Introduction

With the ongoing advent of ever more affordable and accessible Virtual Reality (VR) technologies, the use of VR as a tool for Immersive Learning, in a scalable way, turns into an interesting option that has a potential yet to be exploited. Specifically, the rising ubiquity of smartphone devices, coupled with availability of low-cost, low-end VR solutions that turn the mobile phone into a VR display, allows for envisioning scenarios such as the one described in this work.

Immersive learning technologies in the form of realistic simulations are widely used in medical training [Ruthenbeck and Reynolds 2015], military training [Bhagat et al. 2016], language learning and teaching using Second Life [Jauregi et al. 2011]. Moreover, 3D virtual worlds have been studied through the lenses of immersion and presence perceptions [Slater et al. 2013]. Literature on this topic suggests that the real world and computer-generated environments tend to be blurred with the use of immersive media technology [IJsselsteijn et al. 2006] , [Regenbrecht et al. 2011].

Teaching the specific topics addressed in this pilot study presents a number of challenges when done using only traditional forms of presentation (i.e., whiteboard and image slideshow) that employ mostly text and 2D static imagery. It can be argued that there is a high cognitive load required to build and maintain abstractions that involve three-dimensional space, and to relate them successfully to the goal concepts of the learning activity. The content presentation form proposed in this study is designed to mitigate this cognitive overload by introducing a way to deliver and interact with tridimensional content that offers new possibilities for students to explore these concepts in a way that

DOI: 10.5753/cbie.sbie.2016.410

feels more connected to the subject domain. Indeed, being immersed in the content that was itself an expression of the subject matter in question, that is, studying the global and local illumination models in 3D computer graphics by being immersed inside an actual virtual 3D environment and interacting directly with its lighting parameters, offered potential to simplify the learning effort for this topic, and was also a facilitating factor for the translation of lesson content into an immersive VR experience.

Having the lecture content presented in the form of a VR experience in the classroom also requires available VR equipment with which to show it to the students. In a learning environment, Bring Your Own Device [Johnson et al. 2016], known as the acronym BYOD, describes the practice of having students bring their own smart mobile devices into the classroom and laboratory, to be used for educational purposes. The application of this practice aims to leverage the trend that personal smart devices are becoming more ubiquitous every day, and apply this availability of technology as an asset in the process of teaching and learning. Of interest to this study are the recent improvements in smartphone graphics capabilities overall, and low-cost ways to turn these devices into simple VR headsets such as the Google Cardboard and other similar kits that exist in the market.

Here we examine the results of presenting Global and Local Illumination lecture of the Computer Graphics Technology course content through a VR simulation in the classroom. The subject topics of these lessons in particular, 3D lighting and reflection models, rendering techniques and algorithms, held a promise to translate particularly well into a VR lecture format for immersive content delivery, as detailed below, in the methods section.

In this pilot study we describe the application in details and discuss preliminary results based on analysis of the participants perceptions collected through presence questionnaire. The immersive learning system works using a Google Cardboard. An experiment was conducted in which students were divided into two groups that viewed the same lesson content: experimental and control group. Our results revealed that the experimental group showed higher levels of presence and involvement as compared with the control group.

2. Presence

Presence is defined as a state of consciousness; the (psychological) sense of being there in a virtual environment which results from the experience of the individual of being immersive in the three-dimensional environment while interacting with virtual reality apparatus [Slater 1999].

In literature, the concept of presence is closely related to the concept of immersion [Slater et al. 2013]. Moreover, [McMahan 2003] discuss that these two concepts are often used interchangeably. [Slater et al. 2013] proposed an important distinction between presence and immersion. According to the authors, immersion is the description of a technology, and develops itself to the extent to which an individual is provided with an inclusive, extensive, surrounding, and vivid display [Slater et al. 2013]. Given that virtual environments presuppose immersion and it is expected that systems with high levels of immersion increase the perception of presence. Presence, in turn, represents the potential psychological and behavioral response to immersion [Slater et al. 2013].

Recently, presence in immersive learning has been discussed. Some of this efforts can be seen in [Wang et al. 2016] in which their research demonstrates that participants feel more present in 3D immersive learning environments.

Moreover, [Lombard et al. 2009] declare that presence is a "multi-dimensional concept; i.e., there are different types of presence". For example, these different types can be extended to social presence and co-presence. It is important to point out that beyond the context of virtual environments, presence is also being investigated in traditional classrooms, and especially in online learning environments as social presence factor in order to measure the degree a learner feels personally connected with other students and instructors [Tu 2002], [Tu and McIsaac 2002], [Sung and Mayer 2012]. [Horzum 2015] claims that social presence is one of the most crucial factors to evaluate the quality of online learning experience. Presence has also studied in distance learning immersive environment. [North 2014] has reported preliminary results in which participants felt a high sense of presence in the immersive environment than in the real world.

Given the importance of achieving presence in virtual words, many measurements to evaluate presence are related in the literature. These measures can be clustered into two main categories: objective and subjective approaches. Objective approach records automatic body responses, such as electrocardiogram recordings or galvanic skin responses [Sanchez-Vives and Slater 2005], [Lombard et al. 2009]. If the normal physiological response of a person to a particular situation is replicated in a VR, then this is a indicative of presence. Subjective approaches, in turn, are relied on the participants self-reported experiences. Typically, participants are asked to carry out a task in a virtual reality and then asked to answer a questionnaire. The questionnaire item are measured on a Likert scale between two extremes using a point Likert scale - for example, from -3 meaning "no presence" to +3 meaning "complete presence", with 0 corresponding to "I neither agree nor disagree" [Sanchez-Vives and Slater 2005].

3. Methods

The experiment was conducted in five steps:

First step: pre-experiment compatibility assessment As a way to access the current level of accessibility of the proposed VR tool for the students, they were required to download and install a benchmarking app into their smartphones previously to the experiment. The students would be required in this app to perform a few simple tasks inside a regular (non-VR) 3D environment, allowing for them to get acquainted with the user interface metaphors used throughout the experiment, and for us to have an assessment of how many students would be able to run the experiment on their own devices.

Second step: Experimental and control groups For the experiment, the students were selected randomly into two groups, after positioning themselves in the classroom without prior knowledge that they were to be divided in groups. Every student had access to the same type of cardboard VR headset. Some of the students used their own devices, while the ones that did not have a device available or whose device did not pass the compatibility test executed in the first stage, received smartphones provided by the experiment organization. The first group of 6 was designated as the experimental group, and the other 6 as the control group.

During the experiment, the professor introduced the basic concepts of local and global illumination, such as light sources, diffuse and specular colors, material reflectivity and shader normals. Subsequently, both the experimental and the control group were required to interact with the content provided by the learning system via Google Cardboard [MacIsaac et al. 2015]. The experimental group participants would effect visual changes within the same virtual environment they found themselves immersed in. They were able to freely look around and manipulate settings in objects and light sources in the 3D-scene directly. The control group learned as if they were sitting in a virtual classroom environment, watching the changes effected in the manipulated content through a virtual TV screen instead.

Third step: filling out the presence questionnaire After the professor finished the content explication, the participants were asked to fill up an online presence questionnaire and also asked to answer a set of dissertative questions providing some feedback about the use of the learning system. The dissertative questions were: “Identify and discuss the strengths and weaknesses of this experience”, “Comment on the interface interaction and feature improvements” and “Would you rather learn this content in the form: as presented, slides, video or other (specify)?”.

Fourth step: Content retention assessment Finally, the participants were asked to log in to an online survey form and start a content retention assessment test. This strategy allowed us to investigate whether there is a statistical difference in learning achievement between control and experimental group.

Figure 1. The 3D environment inspired in the image from the lecture material

3.1. Design and development of the immersive learning system

The system is a Virtual Reality 3D environment that allows users to look around an interior environment (Figure 1) inspired on a figure from the course textbook [Watt and Watt 2000], while they interact with underlying lighting and shading model parameters, watching how their changes affect the rendering of the scene in an instant feedback loop. The aim is to familiarize students with concepts in computer graphics rendering algorithms, such as light sources, diffuse and specular colors, material reflectivity and shader normals.

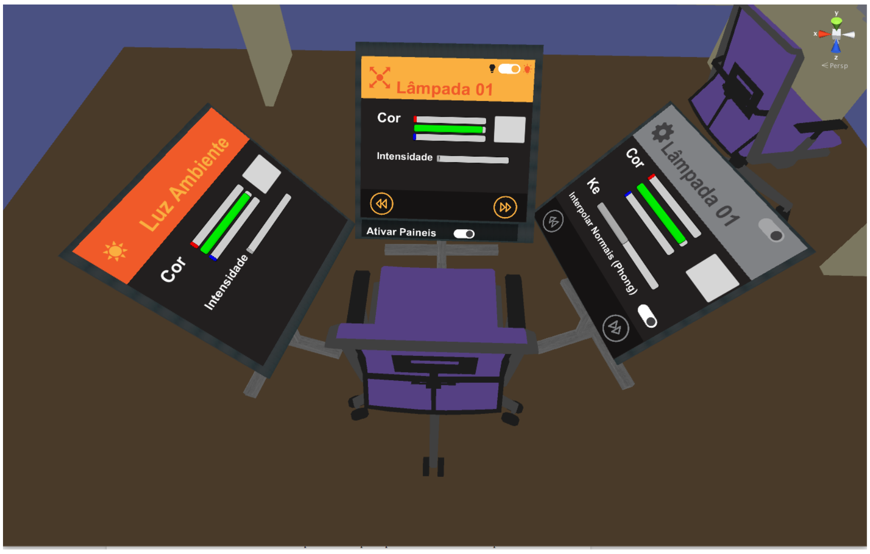

Figure 2. User interface overview. Users can manipulate scene rendering parameters such as light intensities and colors, object colors, and rendering settings.

One of the design elements of this system is the BYOD principle, which encouraged the choice of focusing on mobile VR systems, taking advantage of a user's own smartphone to turn into a VR display when coupled with a simple cardboard assembly and lenses. The system was developed entirely using Unity3D, a popular middleware for the creation of digital games for multiple platforms, and the Google Cardboard Unity3D extension, which provides head-tracking and other features of the Google Cardboard SDK.

To contribute to the element of immersion, a deliberate design choice was made to have the interface available to the user materialized directly in the virtual environment as much as possible (Figure 2), as opposed to having the UI abstracted in the form of 'floating menus' or other such entities that do not appear to be connected to the virtual world in a meaningful way. Through the user interface, the student is able to control a variety of parameters of the global and local lighting models of the scene he is immersed in, such as: light source intensity and color for individual light sources, ambient light intensity and color, and shader parameters of objects in the scene such as material color and reflectiveness.

In order to compare the effect of the degree of immersion on content retention and overall learning experience, two different VR interfaces to the 3D environment were created: the experimental one (Figure 3), viewed directly from inside the same 3D environment being altered, and the control version (Figure 4), where the environment altered

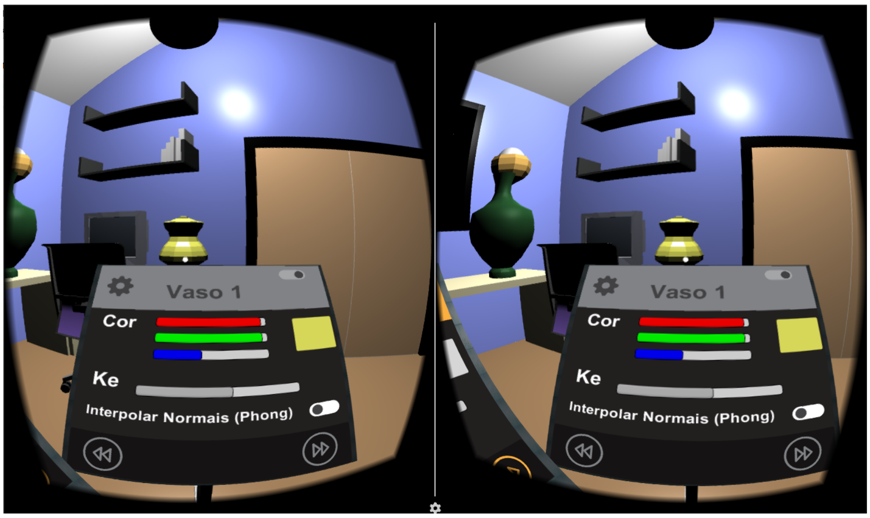

Figure 3. Experimental VR interface. Users are immersed in the same environment that is affected by their changes to lighting and render settings.

by the changes in the rendering parameters were viewed through a virtual window or monitor screen.

3.2. Participants

Twelve participants were recruited to participate in this study (one female and eleven males, age M=25.41, SD= 2.71). They were students enrolled in a graduate level from Computer Graphics Technology module at Escola Politécnica da Universidade de São Paulo.. All the participants were asked to read and sign a consent form to participate in this experiment. There were some criteria for exclusion: being pregnant, previous heart disease, labyrinthitis and nausea in virtual reality immersion.

3.3. Presence questionnaire and qualitative method

After the conclusion of the experiment the participants were invited to complete a 7-item presence questionnaire. Questions were taken from the Igroup Presence Questionnaire (IPQ) [Schubert et al. 2001], translated into Portuguese. The questionnaire was adapted to our particular virtual reality scenario (Table 1). In this study we are interested in analyzing the questions related to sense of being there, immersion and involvement. We discarded the questions that are explicitly related to real environment.

The questions were rated by the participants using a 7-point Likert scale, with -3 ("Totally disagree") and 3 ("Totally agree"), with 0 corresponding to "I neither agree nor disagree".

3.4. Statistical data analyses

Statistical data analyses were carried out using SPSS Version 24. In order to compare the efficacy of the presence induction, a repeated-measures ANOVA was performed between the experimental and control groups.

4. Results

According to ANOVA, the experimental interface results showed to be able to induce presence perception stronger than the control interface [$F(1,11)= 6.41$, $p=.05$, $n=.56$].

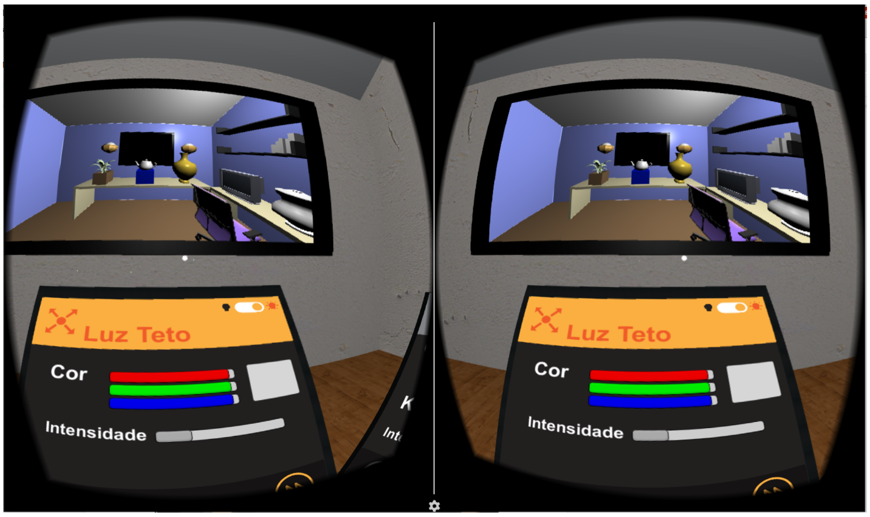

Figure 4. Control VR Interface. Users see the changes in the environment through a virtual window.

Table 1. Questionnaire items

Questions	Experimental Group	Control Group
1	In the computer generated world I had a sense of “being there”.	In the computer generated world I had a sense of “being there”.
2	Somehow I felt that the virtual room surrounded me	Somehow I felt that the environment shown on the TV screen surrounded me.
3	I felt like I was just perceiving pictures.	I felt like I was just watching pictures on the TV screen.
4	I felt present in the virtual room.	I felt present in the environment shown on the TV screen.
5	I was completely captivated by the virtual world.	I was completely captivated by the environment shown on the TV screen.
6	I did not feel present in the virtual room.	I did not feel present in the environment shown on the TV screen.

Moreover, the experimental interface promoted high levels of presence (M= 1.41, SD= 0.78) compared with control interface (M= -0.30, SD= 1.63) (Figure 5). We also observed a higher standard deviation in the control interface. This can be attributed to the user having to move his head back and forth between controlling the UI elements to interact with the scene, and observing the actual effects of changes on the scene, which could be an element of fatigue and confusion when viewing the lecture.

With respect to the interface interaction questions, we observed that there are some limitations about the interface, such as: too many UI controls that must be handled from a single stationary point of reference in space, making the immediate space around the user in the virtual environment cluttered with the UI elements. As some students declared: ”weak points: physical discomfort from having to turn your head around too much; unnatural head movements”; ”in spite of the environment being all around us, having a smaller region of focus might improve comfort in the experience, since having to look back is uncomfortable in the classroom situation.”

Regarding the strengths and weaknesses of the experiment, the system does promote high acceptance to the lecture taught among the students. Some participants reported that: ”The experience offers good immersion. I was able to grasp the lighting model concepts much better.”, ”greater immersion in content, the examples being explained are visualized immediately.”, ”good interactivity with the environment makes it easier to learn

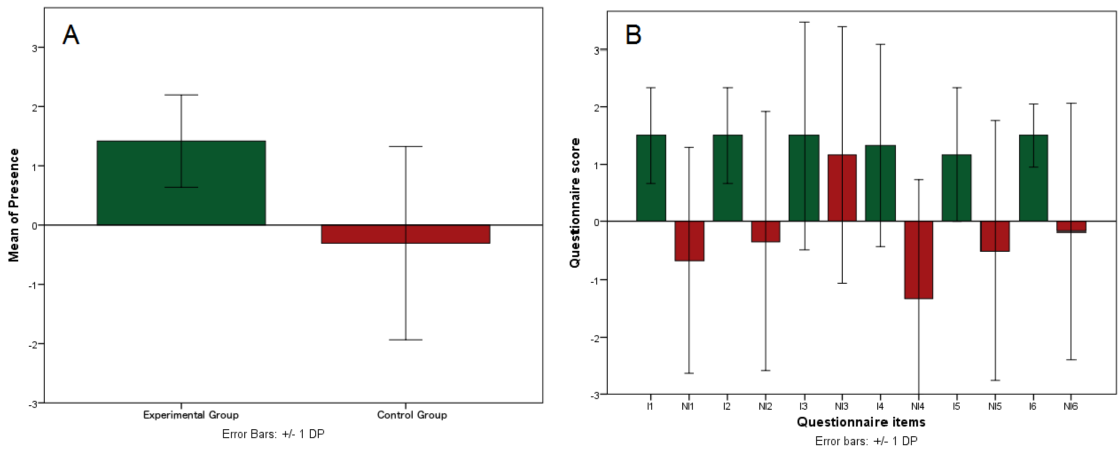

Figure 5. Results of experiment on the experimental and control group, highlighted in green and red shades, respectively. (A) The results showed that the participants rated the presence questionnaire statistically higher in the experimental group than in the control group (B) Questionnaire responses in two groups: experimental (I) and control (NI). Participants indicated their responses on a 7-Likert scale from "I completely disagree" (-3) to "I completely agree" (+3). The bars represent the mean values and the error bars indicate standard errors.

the concepts presented.", "I had an easier time learning computer graphics", "since we are immersed in the virtual environment, we pay more attention to the content."

We also observed that 5 from 6 students from the experimental group would rather learn the content in the form presented. From control group, 2 declared would rather learn the content in the form presented, 2 declared in the form of slides, and 2 declared "others".

5. Conclusion and considerations for further studies

Our pilot experiment showed promising results of using a low cost virtual reality device in a particular lecture of Computer Graphics module. We found that the experimental interface does promote high levels of presence perception compared with the control interface. Our contribution to this field was to show an effective and low cost way to use immersive technology applied to a computer graphics module.

We are already working to improve the system, especially the interaction interface, according to our findings on students comments and recommendations on dissertative questions, and extending the content covered by the immersive learning system, with new topics and new subjects. In the near future we might consider increasing the number of students and, we also might consider students from others courses similar to computer graphics module.

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