Information Recall in a Mobile VR Disability Simulation

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***Abstract*—The purpose of this paper is to investigate the effect of the sense of presence on one aspect of learning, information recall, in a mobile immersive virtual reality (VR) disability simulation (DS). Previous research has found that the use of VR technology in education may facilitate improved learning outcomes. However, it is still an active research topic as the learning outcomes can vary widely and from a practical perspective, mobile VR displays may improve the accessibility of VR while keeping costs low. We hypothesized that a higher level of immersion and involvement in a mobile VR disability simulation that leads to a high sense of presence will help the user to improve information recall. We also looked into whether there is any adverse effect of cybersickness on the information recall task in our DS. The results from our study suggest that participants were able to recall the information effectively and that mobile immersive VR is a feasible modality to facilitate post experience information recall.**

I. Introduction

The advantages of using virtual reality (VR) to facilitate teaching educational objectives are analogous in many ways to the advantages of using an interactive three dimensional (3D) computer simulation. Many studies found that the usage of stationary (e.g., using a teathered head mounted display) VR in education is helpful [1], [2]. However, it is not well studied whether mobile VR can be used to obtain similar results, considering that most trackers and interfaces do not transfer to an unteathered, mobile environment.

Evaluating learning in VR is a difficult problem to approach directly, especially because measurement of conceptual learning is not well defined. Rather than attempting the evaluation of conceptual learning as a whole, in this paper, we investigate the impact of one mobile immersive VR display (i.e. MergeVR) in an information recall task as a more achievable and quantifiable example of the learning activity. In our study, we use the Oxford dictionary definition of "recall" as "bring (a fact, event, or situation) back into one's mind" or simply "to remember". In that sense, information recall is how well people can remember the information they learned previously.

Specifically, this study focuses on how presence, involvement, and flow in a mobile immersive VR disability simulation affect information recall. Presence, involvement, and flow are three common user experience factors that can be affected by immersion. Immersion is a description of a technology, more specifically, it refers to an objective description of what a particular VR system provides. Presence, on the other hand, is a subjective state, the psychological sense of being

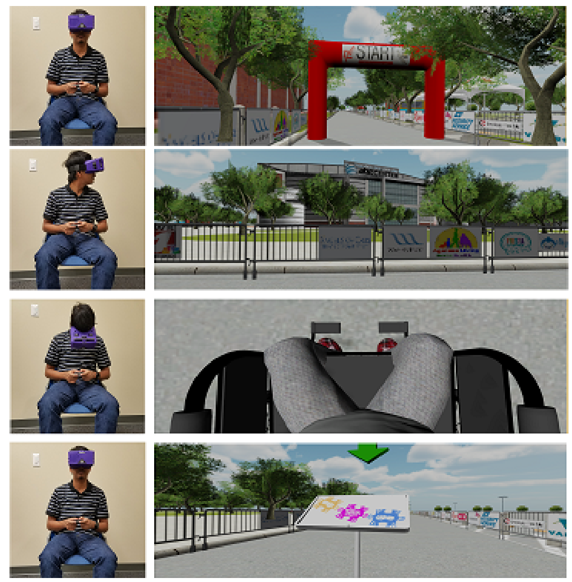

Fig. 1. A participant going through the disability simulation, the view in the VR display, taken at four different times (start of the game, looking left, looking down, and in front of an information board).

"there" in a VR. Involvement, however, is a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events. Involvement depends on the degree of significance or meaning that the individual attaches to the stimuli, activities, or events. Involvement is defined as "a motivational continuum toward a particular object or situation" [3]. Flow, on the other hand, explains the cognitive evaluation and emotional outcomes of the experience. The Presence-Involvement-Flow Framework (PIFF^2) [4] is a psychological research framework to study presence, involvement and flow in VR.

However, it is unclear how presence, involvement, and flow affect learning. Some researchers have found that feeling a high sense of presence greatly improves learning outcomes [5], and participants perform better in procedural memorization task when using a highly immersive VR system [6]. Conversely, other researchers have found that increased presence does not always result in better learning [7]. Hence, it is still an active research topic. Further, cybersickness, which is

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primarily experienced in VR, could potentially have negative effects on learning [8]. There are many different ways to assess cybersickness, however, the most popular is the Simulator Sickness Questionnaire (SSQ) published by Kennedy et al. [8].

In this paper, we investigate the effect of presence on information recall, using a video game like DS setup. According to Flower et al. [9] DS refers to "an approach to modify attitudes regarding people with disabilities is to place people without disabilities in situations that are designed for them to experience what it is like to have a disability". Several approaches have been used to encourage or promote the development of more positive attitudes toward people with disabilities. Educating people without disabilities about people with disabilities using accurate information is one of them. Moreover, the use of various disability simulations among college students has been reported at several campuses [9].

II. Background and Related Work

A. Immersion, Involvement, and Presence

The literature is replete with studies that not only attempt to categorize factors of immersion but also highlight simulator attributes that influence an individual's sense of presence [10]. To experience presence, both involvement and immersion are necessary [10]. According to Moreno et al. [11], HMDs are more immersive than desktop displays and users may experience higher presence in HMDs, which is commonly measured through questionnaires, such as the Witmer and Singer Presence Questionnaire (PQ) [10]. Similarly, the $PIFF^2$ is commonly used to evaluate presence in video games, also used to measure involvement - a motivational continuum toward a particular object or situation - and flow - the subjective, cognitive-emotional evaluation of the game. $PIFF^2$ is considered a validated metric of presence, involvement and flow in digital games [4].

B. Disability Simulation in VR

A number of approaches have been implemented to foster more positive attitudes toward people with disabilities. Flower et al. [9] summarizes some of the categories, such as- showing films presenting a positive image of people with disabilities, educating people without disabilities about people with disabilities using accurate information, and interaction between individuals with and without disabilities in an equal-status relationship. However, the categories of DS strategies have sometimes been criticized for a reported lack of evidence of their effectiveness [12]. Despite the lack of data regarding its effectiveness and the concerns about negative experiences, disability simulation remains a common approach to attempt positive modification of attitudes regarding people with disabilities [13].

C. Education in Virtual Environments

Recent advancement of technology is offering many innovative and promising learning environments. VR is now being used as a means to learn not only concepts and procedures but also basic and complex skills in many fields i.e., conventional flight simulators, surgical simulators, and also in education [1], [2]. VEs can be used to make the learning more interesting and fun with the purpose of improving motivation and attention. Additionally, the usage of VEs in education is also cost effective. Educational VR systems have been developed for the purpose of helping students to learn conceptual information and principles. For example, researchers have prototyped immersive VR systems for mathematics education [14] and for learning complex principles of physics [15].

The relationship between presence and learning is unclear because many studies have found conflicting results. According to Roger Schank, feeling present can contribute to feeling that the consequences of actions performed in VEs and simulations are real and can dramatically improve learning outcome [5]. In a study related to the memorization of object information, Mania et al. [16] found evidence that higher rendering quality significantly increases object recognition. Sowndararajan et al. [6] found that even when greater emphasis on learning new information that is not bound to the specifics of the VE, users performed significantly better in a procedural memorization task when they used a more immersive VE.

D. Cybersickness

While immersive VR technology allows the users to feel a higher degree of presence in the VE, the user can also experience some negative side effects such as disorientation, nausea, headaches and difficulties with vision [8]. When caused by virtual simulators these effects are known as cybersickness or simulator sickness (SS).

III. Hypothesis

The main goal of this research is to investigate the correlation of presence on information recall - an aspect of learning - in a disability simulation using an untethered, mobile virtual environment. To reach our goal, we analyzed each person's presence and their learning evaluation score from a Multiple Sclerosis Questionnaire (MSQ) - a questionnaire based on information presented in the VE.

H: Participants' sense of presence will have a strong correlation with information recall task in our disability simulation's virtual environment.

IV. Methods

A. Participants and Selection Criteria

We recruited 10 unpaid undergraduate students from an anonymous university (eight of them are male) for this study. The mean age of the participants were 19.4 years (SD 4.5).

B. System Description

The VE was designed in Unity 5 - a multi-platform game development system from Unity Technologies. We used a head mounted display named MergeVR with a Samsung Galaxy S4 (SGS4) phone. The SGS4 has a resolution of 1080 x 1920

TABLE I
DESCRIPTIVE STATISTICS FOR PARTICIPANTS' INFORMATION.

# Participants	# Male	# Female	Mean Age (SD)	Prev. WC Use
10	8	2	19.4 (4.5)	2

pixels (441 ppi pixel density) and runs Android OS (v5.2-Lollipop). The participants used a "SteelSeries Free Mobile Wireless" Controller to control their movement in the VE.

C. Virtual Environment

Each year people with MS (along with their friends and family) gather together at AT&T center and participate in an annual fund-raising walk. In our disability simulation, we developed a virtual model of the AT&T center. Similar to the real walk, participants in our study had to navigate around the virtual AT&T center. In addition to that, they had to listen to the audio information about multiple sclerosis (MS) presented along their path. The actual perimeter of AT&T center that was modeled in the VE for the participants to walk around was 1.75 KM. Generally, it takes 20-25 minutes to complete the whole path at normal walking speed. In the VE, the navigation capability was revoked while the audio information was playing to ensure minimal distraction. Thus, the VE experience lasts for about 30-35 minutes. The camera was in first person view mode. If the participant looked down, they could see their virtual avatar sitting in a wheelchair (figure 1). In the VE, we choose to present the information in audio format because our pilot study suggested that hearing the information is less distractive than reading the same information as text inside the HMD.

V. STUDY PROCEDURE

Participants had to sign an ethics board approved consent form to participate in the study. Then they received a brief introduction about the system and an explanation of what they were expected to do in the study.

After the introduction, the participants were asked to sit on a traditional revolving chair. They wore headphones. When participant was comfortable enough to start the study, we started the VR experience. The participants navigated through the AT&T center and had to stop at each information board along their path. They listened to the audio information while waiting in front of an information board. The movement capability was restricted while the audio was playing. When audio was finished, they could start moving again. The whole VR experience continued for about 30–35 minutes.

After finishing the VR experience, the participants filled out a Multiple Sclerosis Questionnaire (MSQ), which consists of questions about the Multiple Sclerosis information presented in the VE. They also filled out a Simulator Sickness Questionnaire (SSQ) and a Presence Questionnaire (PIFF^2). In general, the whole study took approximately 45–50 minutes per participant (VE experience + questionnaires). Participants did not receive any financial benefit. It was an optional extra credit activity for one of their undergraduate courses.

VI. METRICS

A. Questionnaire

The Multiple Sclerosis Questionnaire (MSQ) consists of 11 questions to determine how well the participants recalled the information presented in the VE. Every correct answer carries equal weight towards their MSQ score. To measure presence, involvement and flow of the participants in VE, we used PIFF^2 questionnaire which consists of 14 questions. Each question can be rated from "None" to "Severe" where "None" quantifies as 0 and "Severe" quantifies as 3 towards the calculation of scores in PIFF^2 subscales. The Simulator Sickness Questionnaire (SSQ) is a 16 items questionnaire where each item asks about participants' physiological discomfort. Each item can be rated from "None" to "Severe" where "None" quantifies as 0 and "Severe" quantifies as 3 towards the calculation of SSQ. SSQ has three sub-scales of scores - Nausea, Oculomotor, and Disorientation. The total SSQ score is calculated from these three sub-scales.

B. Statistical Analysis

We analyzed the MSQ, SSQ and PIFF^2 data filled by the participants after finishing the VR experience. Pearson Correlation was used to see how variables are correlated i.e. presence vs information recall, involvement vs information recall etc. All the statistical analyses were performed using IBM SPSS version 19.

VII. RESULTS

A. Questionnaire Result (MSQ, SSQ and PIFF^2)

The PIFF^2 score consists of four dimensions- Presence, Involvement, Cognitive Evaluation, and Emotional Outcome. Descriptive statistics for all dimensions of PIFF^2 is listed in table II.

The Multiple Sclerosis Questionnaire (MSQ) score shows the following result for the information recall task, (M = 236.74, SD = 21.82).

The SSQ questionnaire gives the unweighted value for subscales Nausea (N) = (M = 2.80, SD = 2.39), Oculumotor (O) = (M = 5.80, SD = 3.85) and Disorientation (D) = (M = 4.10, SD = 3.14). From these unweighted three subscales' values, "SSQ Total" was calculated as 125.75 (1).

$$SSQ\ Total = N * 9.54 + O * 7.58 + D * 13.92 \quad (1)$$

B. Correlation Result

In our analysis using Pearson Correlation, we found that there was a significant positive correlation between presence (M = 12.30, SD = 1.34) and information recall (M = 236.74, SD = 21.82) , r = 0.73, p = 0.016, n = 10. There was also a positive correlation between involvement (M = 7.30, SD = 1.16) and information recall (M = 236.74, SD = 21.82), r = 0.66, p = 0.04, n = 10. But no statistically significant correlation were found between cognitive evaluation and information recall. Correlation between emotional outcome and information recall was also not statistically significant. Table II lists more detailed correlation results for different dimensions of the PIFF^2 questionnaire.

TABLE II
CORRELATION RESULT WITH INFORMATION RECALL (* = NOT SIGNIFICANT).

	Mean (SD)	Correlation	p-value
Presence	12.30 (1.34)	0.73	0.016
Involvement	7.30 (1.16)	0.66	0.040
Cognitive Eval^{n}	9.40 (1.65)	0.24	*
Emotional Outcome	15.30 (2.34)	0.28	*

VIII. DISCUSSION

We found significant correlations between presence vs information recall and involvement vs information recall (see VII-B). This result gives a significant boost towards our hypothesis. However, due to the limitation in study design in having only one condition, it is not possible to make conclusions about causality. We believe more investigation should be conducted to further explore this.

The result of the MSQ score is quite high, the ratio between "mean" to "max score possible" is more than 70% (236.74 / 330). Again, due to the limitation of the design, we can not claim this as a concrete result. However, we think there are couple of reasons which may have helped the participants in their information recall task in our mobile VR disability simulation. Firstly, in our opinion, participants were immersed in the VE as there were almost zero external stimuli present from the outside world. The absence of any outside stimuli gave the participants an environment where distraction was minimal. This might help them to feel involved into the VE more. As a result of their undivided attention towards the VE, the sense of presence was higher. Another reason could be the unique experience that our disability simulation provides to the participants where they could see their virtual avatar in the wheelchair from a first person perspective. This unique experience may have enabled them to connect with people with MS and remember facts presented in the VE. Moreover, our DS may have created a positive attitude towards the people with MS and it might have helped them in their information recall task. More research needs to be done before we can evaluate all these claims.

The SSQ questionnaire results from our study suggest that HMD is more prone to induce the cybersickness compared to the desktop display. Sarah et al. [25] also found the similar result in their work where they compared different display systems (i.e. HMD, desktop and projection display system). Although we did not have additional conditions, the SSQ score in our study was relatively high based on the literature, which means participants did feel cybersick in our mobile VR disability simulation.

IX. CONCLUSION AND FUTURE WORK

In this paper, we presented an experimental study investigating the effects of presence in a mobile immersive virtual environment for one aspect of learning - information recall - in a disability simulation style application. The results from our study suggest that the sense of presence was strongly correlated to information recall of MS facts, despite feelings of cybersickness.

In the future, we aim to evaluate the effect of presence (in different VR conditions) on information recall tasks and determine what causes increased presence and information recall. Moreover, using a full body tracking system, integrated with our current mobile VR disability simulation, we also aim to investigate the effect of the sense of embodiment on information recall in VR disability simulation.

We think with the proper setup, disability simulation (DS) might be a helpful means to raise awareness towards the people with disabilities. In our future studies, we plan to investigate the concept of Disability Simulation in more in depth fashion for different types of disabilities.

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