Comparison of 3D Display Technologies for Embodied Interaction in Virtual Hands-On Experiential Learning

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Abstract: This study aims to explore the effect of different 3D display technologies on hands-on virtual experiential learning environment (VELE). We tested three display technologies, VR HMD, 3D projection and AR HMD, in two math learning scenarios. Different display techniques significantly affected user experience in learning. Results on visual comfort, flow experience, and learning experience in the VR HMD condition are significantly higher than those in 3D projection and the AR condition. We conclude that VR HMD contributes to better viewing experience and learning experience for hands-on VELE in the scenarios tested. Whether the results still hold reliably in more complex learning activities and long-term learning need to be further studied.

Introduction

Experiential learning can be an effective way to promote learning interest. Through interactive and hands-on experience, learners not only can transfer the experience gained through learning activities into the construction of knowledge, but also develop positive intrinsic interest and extrinsic behaviors (Huang et al., 2016). Experiential learning requires appropriate tools, locales, and equipment, some of which are difficult to create (e.g. different ecosystems) or experience (e.g. surgical operations). It has been therefore often limited with fixed locations (e.g. mechanical assembly). With the advancement of digital media, real-time virtual reality (VR), and augmented reality (AR) technologies, various types of experiential learning now can be designed in new ways. These new technologies support the creation of vivid, lifelike virtual experiential learning environment (VELE), with some already showing superiorities over traditional learning (Furió, Juan, Seguí† & Vivó, 2015; Alhalabi, 2017).

In VELE, embodied interaction (EI) design is a way to enable people to interact mentally as well as physically with information technology and has been considered as a human-computer interaction approach for improving interaction efficiency and interaction experience (Zhang, Li, & Wachs, 2016). Learners in a VELE is supported with intuitive embodied experience which may reduce their cognitive load and contributes to the internalization of knowledge (Furió, Juan, Seguí† & Vivó, 2015). Different VR technologies have been applied in VELEs where display characteristics maybe a key factor influencing user experience, especially for EI design. In this paper, we present a study of three immersive display technologies to test how they each enhances viewing experience and interaction efficiency in experiential learning.

Participants and experimental design

A total of 26 volunteers (15 males and 11 females, 23.00±3.34 years) participated in the experiment. We adopted a single-factor within-subject design. The within-subject factor is 3D display modes which include 3 conditions: VR HMD, 3D projection, and AR HMD. Except for the display technology, other factors were controlled among the three conditions. There are six dependent variables: visual comfort, flow experience and four learning experience indicators (intrinsic interest, concentration, behavior intention, and presence). The presentation order of different display modes was counterbalanced.

Experimental mission and apparatus

We constructed a VELE for math learning and designed two learning scenarios (Figure 1). Users explore the digital scenes and manipulate virtual objects using HTC vive handheld controllers which are represented in the virtual environment as a pair of virtual hands. Users may feel like that they are manipulating the virtual objects with their own hands (Figure 1). The two learning scenarios are used with three display modes (Figure 2).

Scenario 1: Calculation of Cone Volume

Scenario 2: Tower of Hanoi problem

Figure 1. Two mathematic learning

VR HMD 3D projection AR HMD

Figure 2. Experiencing the VELE in three display conditions.

Results and discussion

We performed repeated measurement analysis of variance. Results are shown in Table 1. Different display techniques/conditions are indeed an important factor affecting experiences in VELE. As illustrated in Table 1, for the majority of the indicators of visual comfort and learning experience, the values in VR HMD condition are significantly better than those in 3D projection and AR HMD condition. Within the scenarios tested in this study, VR HMD contributes to better viewing experience and learning experience for hands-on VELE.

Table 1: Descriptive statistics and Difference test results in different display condition.

Display conditions	3D experience *M(S.D)*	Naturalness *M(S.D)*	Image quality *M(S.D)*	Viewing experience *M(S.D)*	Avoidance of discomfort *M(S.D)*	Flow *M(S.D)*	Intrinsic interest *M(S.D)*	Behavior intention *M(S.D)*	Concentration *M(S.D)*	Presence *M(S.D)*
VR HMD	4.42 (0.95)	4.28 (0.93)	4.31 (0.84)	13.58 (2.18)	8.92 (1.32)	63.77 (8.04)	12.88 (1.92)	12.50 (1.96)	9.08 (1.96)	12.58 (1.90)
3D Projection	3.88 (0.95)	3.88 (0.88)	4.08 (0.84)	10.38 (3.20)	8.15 (1.84)	56.12 (11.68)	11.23 (2.97)	10.69 (2.91)	9.19 (1.67)	10.42 (3.32)
AR HMD	3.73 (1.04)	3.64 (0.99)	3.77 (0.91)	9.770 (3.15)	7.65 (2.19)	52.12 (16.2)	11.19 (3.32)	10.38 (3.59)	8.69 (1.59)	10.81 (3.15)
F value	3.404*	2.933	2.204	12.532**	3.638*	6.206**	3.018+	4.406*	0.585	4.211*

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