Enhancing VR Experiential Learning through the Design of Embodied Interaction in a Shared Virtual Environment

Research-in-Progress

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Abstract

Virtual Reality (VR) has great potentials for experiential learning, especially in a shared environment with multiple users. However, the factors influencing such experience are not well understood. This research considers one specific feature of VR, the embodiment richness. We consider embodiment richness a powerful feature because VR supports various media and the immersion with the entire physical body, which could facilitate the design of dynamic interactions, embodying both physical information and social activities. We propose a conceptual framework for its influences on VR experiential learning through engagement and communication. Aside from retrospective questionnaires, our methods also incorporate a physiological measure with brain sensing technology, reflecting the cognitive process. This will be a contribution of our work. This research will also contribute to the theoretical framework to understand the effect of embodiment in VR experiential learning, informing the future design and application of VR for experiential learning in practice.

Keywords: virtual reality, experiential learning, embodied interaction, embodiment richness, presence, spatial presence, social presence, engagement, communication

1. Introduction

Virtual Reality (VR) is an immersive technology that is becoming increasingly affordable and prevalent thanks to the recent advance in hardware manufacturing and software development. It supports an immersive virtual environment, allowing users to experience and to interact with a simulated world through a headset and tracked controllers. VR has been used for military trainings and medical operations (Sutherland, 1965). It also supports a 'time travel' that brings users back to experience the past (Ch'ng, 2009). Such immersion in the environment and the narrative it constructs could provide users a first-person perspective so that they can actively engage in the experience, making it stand out from the use of traditional media such as texts, images, and videos for learning. This advantage has been recognized by museums and exhibitors who are actively adopting digital technologies for museum education. Recent study indicated that VR can be used as a mode for the experiential learning of cultural heritage (Ch'ng, Li, Cai, & Leow, forthcoming). It could potentially enhance the learning outcome with its immersive and vivid visualizations, richness in media and interactivity, and support for social interaction with multiuser experiences in a shared environment. VR as an immersive digital technology could afford more diverse ways for presenting information and facilitating social interactions, specifically, through its richness of embodiment, that is to provide visible or tangible forms of abstract concepts such as ideas and feelings. Such richness in embodiment is potentially a useful feature of VR to facilitate the understanding of experiential learning, yet, it was rarely explored in a systematic way. We define embodiment richness as the amount of information and social activities that can be perceived through embodied interactions. This describes the conventional design concerns of presenting

information in a virtual environment, mainly through interactions afforded by objects. More importantly, it addresses the effect of social activities that often occur in a social context, where intentional or completely unintentional cues affect people's behaviours. This research focuses on the design of embodied interactions to enhance VR experiential learning in a shared virtual environment. We propose such influence can be mediated by both embodiment of information and social activities.

2. Literature Review

2.1. From Affordances to Embodied Interaction

The term affordance was coined by James J. Gibson to describe what an environment offers, provides, and furnishes the animal from the ecological psychology point of view (Gibson, 1978). It was brought into the discussion in the field of Human Computer Interaction (HCI) by Donald Norman, initially defined as 'a relationship between the properties of an object and the capabilities of the agent that determines just how the object could possibly be used' in his book *The Psychology of Everyday Things* (Norman, 1988). The definition includes both actual and perceived properties of objects, indicating the visible affordance to agents and the possible actions without need for instructions. While affordance is a useful principle to imply action possibilities offered by objects in the environment, it is limited for situations that involve people, culture, and social group, where people learn what to do and how to behave by watching others or through their trails. Such social structures are more complex than the world of stand-alone objects and are beyond what perceived affordance could explain. Such limitations have also been identified by other researchers, arguing to adopt a mediated action perspective of affordances to understand the possible actions in cultural environments (Kaptelinin & Nardi, 2012).

Informed by phenomenology, Dourish (2001) proposed the framework of embodied interaction, addressing more than a physical reality, but rather a participative status, exploiting the physical and tactile skills, as well as the social skills and aspects of social setting. Information can be embodied in the virtual objects, through the visualization of the contexts and narratives with dynamic controls and interactivity. For example, in a virtual museum, even though the historical information of an artefact can be presented using plain texts, images, and audios, mimicking the way that museums adopt, such a passive viewing approach can be transformed to support active interactions with the rich digital media supported by VR, such as the use of a virtual avatar as a tour guide. The social embodiment refers to the representation of others to facilitate the visual perception. Designing embodied interaction in a virtual environment to embody information and the presence of others could facilitate the control and enhance communication (Li, Tennent, & Cobb, 2019; Smith & Neff, 2018). It is also indicated that embodied interaction in simulations could enhance student engagement and learning (Lindgren, Tscholl, Wang, & Johnson, 2016).

2.2. Spatial Presence and Social Presence

A mediated experience usually involves the concept presence, illustrating how a medium is perceived. Different conceptualizations of presence have been used, emphasizing various aspects, such as realism, transportation, immersion, and social richness. Lombard and Ditton (1997) defined presence as 'the perceptual illusion of nonmediation'. A mediated experience provides the user with a strong sense of presence when it seems like it is not mediated. Here in this research, we specifically look at two dimensions: *spatial presence* (Heeter, 1992), and *social presence* (Biocca, 1997). The immersive experience supported by VR usually engages users with a strong spatial presence, making them believe that they were physically situated in the virtual world, namely, the sense of *being there*. It illustrates users' compelling sense of being in environment represented by the medium. When in shared virtual environment with others, users may also perceive social presence, the sense of *being together with another*. It evaluates users' ability to connect via a medium. Both spatial presence and social presence can be measured with questionnaires (Biocca, Harms, & Burgoon, 2003).

2.3. Engagement

The term engagement stands for the state in which people feel connected with an object or being immersed within a context. Various conceptualizations of the term have been proposed in previous

research such as the near-obsessiveness for game players (Alison, 2003) and the cognitive and affective commitment to a brand (Mollen & Wilson, 2010). Despite the various context-related aspects considered in the past literature, most of these conceptualizations mentioned two main ingredients in the engagement which include the active interactions with the objects and the maximized usage of cognitive and affective effort. We adopt the definition of engagement as 'active, goal-directed, flexible, constructive, persistent, focused interactions with the social and physical environments' (Furrer & Skinner, 2003), as it fits the context of shared virtual environment and reflects our proposed embodiment richness, where both information in the environment and social activities are concerned. It is believed that active interaction is closely associated with engagement and there is empirical evidence showing that students in the kinaesthetically-enhanced learning environment showed an increased engagement (Lindgren et al., 2016).

2.4. Interpersonal Communication

Interpersonal communication refers to the exchange of information between two or more people. One of the main aims in interpersonal communication research is to understand how humans use verbal and nonverbal cues to accomplish a number of personal and relational goals (Berger, 2005). With the wide adoption of the new communication technologies, the notion of computer mediated communication (CMC) became the focus of the communication research. Compared with face-to-face communication, the loss of nonverbal cues in traditional CMC influences a variety of outcomes including the amount and the rate of social information exchange (Walther, 1996). However, in the multiuser VR context, which could provide a highly interactive and synchronized communication environment, it could remedy the non-verbal cues in traditional CMC to further simulate the 'face-to-face' communication. Although certain cues such as micro expressions are still limitations of VR, the involvement of entire body in an immersive experience could preserve most social cues existed in face-to-face communication, across time and space. Research in education and collaborative work have emphasized the significance of interpersonal communications to learning outcome (Montoya, Massey, & Lockwood, 2011; Piccoli, Ahmad, & Ives, 2007). Investigating how effective users communicate in a shared virtual environment could contribute to the understanding of VR experiential learning.

2.5. Experiential Learning in Virtual Reality

Experiential learning is the process of learning through experience. According to Kolb's experiential learning model, the learning cycle includes four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). It illustrates a process where learning happens throughout and after an activity. Although there is no specific stage to start with, all four stages should be performed for successful learning. Lombardo and Eichinger (1996) proposed the 70/20/10 model for learning and development. They found that around 70% of the learning is associated with the experience, 20% through the social activities with others, and 10% from structured courses and programs. This supports the use of VR for experiential learning in that users in an immersive environment usually engage in an experience with their entire body. Their interactions with the world involve body movements and their attentions are attracted by various visual and auditory cues, and even haptic feedback. These offer them a multi-sensory and engaging experience. For a multiuser environment, the inputs from others could further facilitate learning by introducing social activities and supporting users' perceived social presence (Li, Ch'ng, Cai, & See, 2018). In addition, a recent study indicated that VR's support on the sense of immersion and embodiment offers users diverse interactions, making it of great potentials to facilitate experiential learning (Ch'ng, Li, Cai, & Leow, forthcoming).

3. Conceptual Framework

Our conceptual research framework is illustrated in Figure 1.

In the past literature, Markus and Silver (2018) proposed two main factors in the ICT adoption and use - functional affordance and social affordance. Besides, some other researchers also suggest that physical aspect and psychological aspect are two key components in HCI, for example, Kaptelinin and Nardi (2012) proposed the handling affordance and effecter affordance to illuminate the mediated action perspective in HCI. In this paper, we propose that the user's experiential learning outcome could be influenced by embodiment richness through both information embodiment and social embodiment.

Moreover, the two widely-used concepts, engagement and interpersonal communication, have been introduced to test the effect of these two types of embodiment to the experiential learning outcome.

Research has shown that the spatial presence is essentially grounded in the ability of doing. The greater the technology's affordances for intended actions and the more attention user allocated to the environment, the greater the sense of presence (Schultze, 2010). Through information embodiment in the virtual environment, users' attention is likely to be attracted and sustained through the richness of sensory stimulation and interactivity, and the affordance in embodied interactions could also facilitate their intended actions. This indicates that users' perceived spatial presence can be enhanced through the embodiment richness, mostly, information embodiment. Hence:

H1. Embodiment richness positively correlates with spatial presence.

Social presence, on the other hand, is affected by social cues in the virtual environment. A high social presence means users could perceive others' intelligence. As afforded by avatars, they could convey agency and behavioural realism, providing social cues to users. Therefore, avatar, a social embodiment, is considered to be able to enhance social presence (Blascovich et al., 2002). Lack of embodiment of others could lead to doubts and dissociation of interactions (Heeter, 1992), which negatively affect the social presence and result in a degrade in communication (Smith & Neff, 2018). Hence:

H2. Embodiment richness positively correlates with social presence.

Users with a high level of spatial presence indicates that they perceive a greater level of immersive experience in terms of their physical location. Schultze (2010) claims that the higher of the spatial presence the user perceived, the more absorbed and emotionally engaged the user becomes. The spatial presence shall encourage user to actively interact with the environment and reduce the cognitive effort in processing the surrounding information with appropriate cues and mappings between their actions and perception of the world. Besides, past literature has tested the effect of spatial presence on engagement in e-learning, showing a positive relationship (Guthrie et al., 2004). Hence:

H3. Spatial presence positively correlates with engagement.

The relationship between social presence and interpersonal communication has been studied extensively in the context of social media (Pongpaew, Speece, & Tiangsoongnern, 2017), online learning (Shea & Bidjerano, 2009), and virtual community (Cheung, Chiu, & Lee, 2011). Social presence indicates that communication exchanges are sociable, warm, personal, and sensitive (Short, Williams, & Christie, 1976) and is usually primarily influenced by the medium of communication (Kear, 2010). In a shared virtual environment, users will interact with other users to explore the shared space, and the perception of a warm and real social connection could help users to formulate commitment and bond with each other. Therefore, this sense of being in the community and closeness with others could promote frequent and effective interpersonal communication. Hence:

H4. Social presence positively correlates with interpersonal communication.

Most research about engagement stated that the engagement involves both cognitive and affective aspects. In the multiuser VR context, engagement could promote active interactions within a physical and social environment and can be facilitated by goal-settings. Therefore, it supports the interpersonal communication by providing an active communication environment and a shared feeling about the context. An example could be found in Kearsley and Shneiderman (1998) that engagement could boost the inner-group discussion, especially in high drop-out learning environment like teenagers and distance learners. Considering the nature that VR attracts the youngsters most (Ch'ng et al., forthcoming), it is important to support and sustain user engagement to facilitate discussions and communication.

Besides, engagement has been widely used and proven effective in learning in past literatures. It is evidenced that engagement could encompass both collaborative and communicative interactions within the group, which results in active learning (Kearsley, GKearsley, G., & Shneiderman & Shneiderman, 1998). It could also denote the state where people fully exploit of their cognitive systems to interact with the objects in a learning environment (Guthrie et al., 2004). Given the fact that experiential learning requires people's cognitive effort to observe, reflect, and act through the experience, engagement shall provide helps to people in improving learning outcomes. Hence:

H5. Engagement positively correlates with interpersonal communication.

H6. Engagement positively correlates with experiential learning outcome.

Interpersonal communication is one of the most important factors which could influence the learning outcomes of collaborative learning, experiential learning and social learning. Piccoli, Ahmad and Ives (2007) claimed that the interactions between students enable them to verbalize their understandings and ideas through posting comments, asking and answering questions, and this verbalization process could lead to self-explanation and help them articulate their knowledge absorption. In addition, interpersonal communication could facilitate the information exchange process. It was found that appropriate frequency and ease of communication could lead to better performance in collaborations and learning among team members (Montoya et al., 2011). Hence:

H7. Interpersonal communication positively correlates with experiential learning outcome.

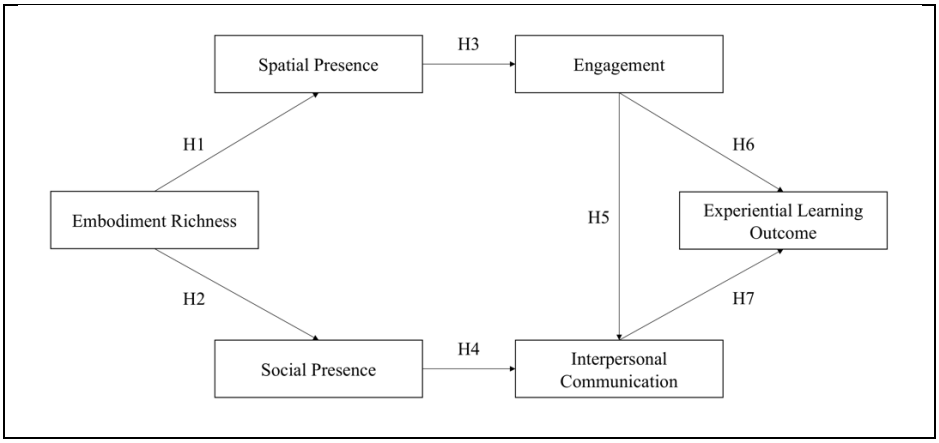

Figure 1. Conceptual Research Framework

4. Methodology

A virtual environment of an exhibition hall has been constructed with multiple cultural heritage artefacts and their associated information. Photogrammetry and 3D modelling techniques were used to capture and reconstruct the 3D models of cultural artefacts. Interactions with artefacts have also been implemented, such grabbing using controllers to enable viewing from different perspectives. In addition, a network has been established to host several users in the same virtual space with their positions and interactions synchronized. We used Blender for 3D modelling, and Unity with C# scripting for the interaction design. An initial user study has been carried out to evaluate the virtual environment and its use for social interactions, confirming the usability and the technology acceptance. These have established a foundation for the research on the proposed framework.

Table 1. Controlled Experiment Setting

	Information Embodiment	Social Embodiment
Setting A	High	High
Setting B	High	Low
Setting C	Low	High
Setting D	Low	Low

A controlled experiment will be carried out to test our hypotheses and the proposed framework. As the embodiment richness includes the information embodiment and social embodiment, a 2x2 group of experiments will be conducted to study the effects of embodiment richness as an influencing factor (see Table 1). High information embodiment illustrates a great amount of shared information that

participants perceive during their interactions with the objects, environment, and others; and high social embodiment can be achieved through the presence of tracked and synchronised virtual avatars. Tasks will be given to participants, such as arranging the artefacts in chronological order, so that the learning outcomes can be measure afterwards.

Mixed method of research (Creswell & Clark, 2017) will be adopted to incorporate both qualitative and quantitative data in order to confirm the research findings from different viewpoints. Questionnaires with Likert-style questions have been developed and validated to measure spatial presence and social presence (Nowak & Biocca, 2003), as well as the user engagement (Brockmyer et al., 2009). In addition, ethnomethodology will be used to understand user communications. It is an approach that has been used widely to study collaboration in Computer Supported Collaborative Work, which primarily studies the practical social action and objective reality of social facts (Garfinkel, 2016). Moreover, the Conversation Analysis can be adopted as an approach to exploring the nature of interactions and communications. These can also reveal users' reflections during the experience and possibly their active practices, informing certain aspects of the experiential learning, which can be cross-examined with the learning outcomes measured using questionnaires.

Questionnaires are often subjective measure that are self-reported and retrospective. One of the highlights of our research is that we will also adopt a brain sensing measure to record physiological data, providing a continuous and objective presentation that allows the understanding of the cognitive process. Brain sensing devices are becoming increasingly affordable for its use in research projects, mostly for the purpose of evaluation studies in the HCI community. However, few have used it for VR experience evaluation, partially because most brain sensing devices sit directly on users' forehead, while VR headsets are also positioned on the head. The simultaneous wearing of these two devices could be problematic. Nevertheless, previous study evaluated two brain monitoring devices and found that no additional discomfort was reported with the Muse headset (Pike & Ch'ng, 2016). Data collected will be processed and analysed across the four experiment settings to test the proposed hypotheses.

5. Conclusion

This research attempts to explore the role of embodiment richness in enhancing the VR experiential learning. A conceptual research framework is proposed, and seven hypotheses are provided regarding the relationship between embodiment richness, spatial presence, social presence, engagement, interpersonal communication, and experiential learning outcome. Initial technical setup and user study have laid a foundation for this research. As a theoretical contribution, we propose the concept of embodiment richness in virtual environment, categorizing it into information embodiment and social embodiment. The proposed framework also has practical values in informing the future design of embodied interaction for VR experiential learning, taking into account the user engagement and interpersonal communication. Finally, our adoption of the brain sensing technology with physiological measures in evaluating VR experience will be another contribution in terms of research methodology.

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