Effects of background complexity and familiarity on presence and work performance in a VR manual task

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Abstract. Recently, virtual reality (VR) technology has been commonly applied in our daily life and widely used as a tool for various industries. Considering occupational injury, accidents, and medical dispute that happen frequently in the workplace nowadays, it has become a valuable key solution if we could apply VR applications sufficiently for education and trainings purposes in a simulated work environment. Under different design settings in a virtual environment (VE), e.g. user interaction interface, visual complexity, task dynamics, physical fidelity, etc., it may induce the users experiencing various scales of presence, immersion, task familiarity, and simulator sickness and further affect the user performance and simulation effectiveness. In this study, we aim to investigate how the VE users are affected by the background complexity and familiarity in their presence perception and work performance. In the experimental design, background complexity has been set for high and low levels, and the familiarity parameter has been considered based on a cultural aspect. In a first part of this study, we apply own questionnaires in interviews with participants from different cultural backgrounds for classifying the virtual objects into different culture categories. Based on the user evaluation outcome, several virtual workspaces are constructed using distinguished cultural items. Participants perform a manual manipulation task in several pre-defined VE's involving different complexity levels and with own- or unfamiliar- culture settings. A pilot experiment shows that the background complexity and familiarity could affect the user performance. In the end phase of this study, we aim to investigate the user perception and behavior as well as the work performance in such a VR manual task influenced by the settings of the background environment. Findings are anticipated to bring in some important design concepts and considerations for simulating a workspace for future applications.

Keywords: presence, virtual reality, background complexity, familiarity, cultural ergonomics

1. Introduction

The design and implementation of high-quality VR requires intense knowledge of various disciplines, such as behavioral and social sciences, neuroscience, computer science, physics, communications, art, and even philosophy. VR is getting very popular also a useful tool, however, there are some potential adverse health effects of using a VR system, such as nausea, eye strain, headache, vertigo, physical injury,

transmitted disease, and also some aftereffects (Kennedy and Fowlkes 1992). The sickness level of a VR user has become an indicator for the quality of the VR system. Questionnaires or symptom checklists are the common means of measuring VR sickness. The Simulator Sickness Questionnaire (SSQ) was created by analyzing data from flight simulators, and 16 discomfort symptoms were established and validated (Kennedy et al. 1993). The SSQ has become a standard for measuring simulator sickness, and the overall severity factor may reflect the best index of VR sickness. The Motion Sickness Susceptibility Questionnaire (MSSQ) developed by Golding (2006) is a measurement of a person's susceptibility to sickness before exposure to VR. MSSQ can predict individual differences in motion sickness caused by a variety of stimuli. MSSQ combined with SSQ is the most frequently used method to measure VR sickness.

Presence is a sense of "being there" inside a space even when physically located in a different location. It can also be described as the way the user subjectively experiences the immersion. Immersion is the real objective degree to which a virtual reality system and application projects stimuli onto the sensory receptors of users in a way that is extensive, matching, surrounding, vivid, interactive, and plot informing (Slater and Wilbur 1997). Presence level of a VR user is also an indicator for design quality of the VR system. The most frequently used method for measuring is the Presence Questionnaire (PQ) developed and revised by Witmer (1998, 2005).

Researchers have conducted studies of virtual reality in entertainment, disease treatment, military training, etc. However, the research of simulated workspace design in human ergonomics is relatively scarce. Thus, more studies in this field are needed. This study aims to design simulated workspaces and investigate factors that can affect presence and simulator sickness level in the simulated workspaces to provide advice for future simulated workspace design. The sickness levels are measured by SSQ and MSSQ, and the presence level is measured by PQ. Because simulator sickness and break-in-presence can decrease the task performance of the user in a simulated workspace (Jerald 2016, Witmer and Singer 1998), it is essential to understand what factors can affect the presence and simulator sickness level for a better-simulated workspace design. We focus on the factors "background familiarity" and "culture" because on the one hand, people may feel more present and less sick if the virtual workspace looks similar to the workspace present in their daily lives, i.e. they may have better task performance in their familiar workspace. On the other hand, the preference of the simulated workspace has individual differences, and people with similar cultural background may have the similar choice because the same social system and culture they share (Nisbett 2003).

2. Method

2.1 Participants

From April 2018, we have recruited 50 participants through posting advertisement in several university campuses 20 participants included in the first pilot study are from 19 to 52 years old (M=26.35, SD=7.96). Nine are European (four males, five females) and 11 are Asian (three males and eight females).

2.2 VR experiment

A LEGO® sorting experiment has been designed. Participants wore a HMD and were asked to sort some LEGO® bricks randomly displayed on a desk into 6 corresponding boxes by its color (3 types: blue, yellow, and red) and its shape (2 types: 2x2-sized bricks and 4x2-sized bricks). A time duration of three minutes was given to each participant for performing his/her sorting task in each test condition (three virtual rooms) as demonstrated in Fig. 1. Virtual items used in the three rooms were either downloaded from Google 3D Warehouse or self-made. Those three rooms were: a) Basic virtual room: with the main settings of LEGO task only – three desks, six boxes, LEGO bricks; participants have the lowest familiarity for this environment and the familiarity scale for this room is considered to be 1 (not at all familiar). b) Asian-style virtual room: with the main settings of LEGO task, added virtual walls, fixed virtual items, and typical Asian style virtual items. c) Western-style virtual room: with the main settings of LEGO task, added virtual walls, fixed virtual items, and typical Western style virtual items.
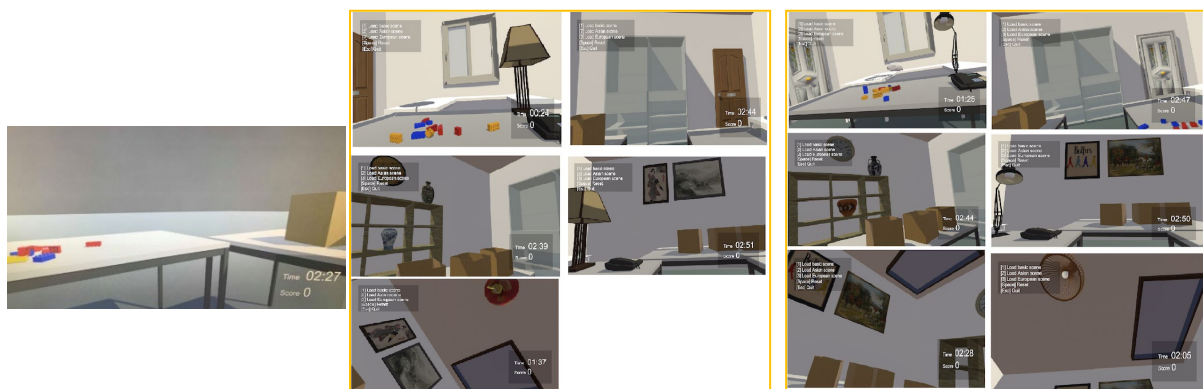

Figure 1.   (Left) The Basic virtual room. (Middle) The Asian-style virtual room. (Right) The Western-style virtual room.

2.3 The questionnaires

Before designing and constructing the virtual rooms, a self-designed Item Choice Questionnaire (ICQ) was used to measure the cultural background of participants, as well as their familiarity scale of virtual items was used. This ICQ asked participants to rate the familiarity scale of 50 virtual items using a 5-point Likert-Type scale (1=not at all familiar, 5=extremely familiar). It also asked about participants' necessary demographical information and their decoration preference of virtual workspace.

The Motion Sickness Susceptibility Questionnaire, the Immersive Tendency Questionnaire (ITQ), and the Simulator Sickness Questionnaire (SSQ) have been applied before the LEGO task. After the simulated tasks, participants have been requested to continue filling out the Presence Questionnaire (PQ) and SSQ to conclude the experiment (Witmer and Singer 1998, Kennedy et al. 1993). The original PQ consists of 32 items considering factors of control factors, sensory factors, distraction factors, and realism. In this study, we have adapted to an alternative version of the original PQ using 24 items of the original 32 items with subscales with slightly different combination of items (realism, possibility to act, quality of interface, possibility to examine, self-evaluation of performance, and

excluding "sounds" and "haptic" items which are not applicable in this study design) (Robillard et al. 2002).

3. Results

The data collected from the ICQ was analyzed to find out the familiarity scales for the different virtual rooms of participants. We found that Asian participants have higher familiarity (M= 3.22, SD=0.50) than Western participants (M=2.75, SD=0.98) for the Asian-style virtual room, while Western participants have higher familiarity (M=3.39, SD=0.86) than Asian participants (M=2.78, SD=0.64) for the Western-style virtual room, the results are not statistically significant.

The effect of background familiarity on total presence level was tested by comparing the participant's total presence level in three virtual rooms. The participant's total presence level in the Asian-style virtual room (MD=-7.83, SD=10.84, t(17)=-3.07, p=.007) and the Western-style virtual room (MD=-6.22, SD=10.70, t(17)=-2.47, p=.025) are statistically significantly higher than the presence level in the Basic virtual room, which indicates that background familiarity have a statistically significant effect on total presence level.

The effect of cultural background on total presence level was investigated by comparing the total presence level of Asian participants and Western participants in both virtual rooms. In the Asian-style virtual room, Asian participants have higher total presence level than Western participants (MD(W-A)=-1.48, t(16)=-.44, p=.67). Western participants have higher total presence level than Asian participants in the Western-style virtual room (MD(W-A)=3.73, t(16)=1.14, p=.27). Those results might result from the effect of culture, but they might also result from the training or learning effects that often happen in a VR task. In this study, the represented order of the LEGO sorting task to Asian and Western participants were different, the order is: basic room -> other culture room -> own culture room. So, there is a considerable chance that those results were resulted from training or learning effects. Therefore, the mean difference of total presence level in participant's own cultural background and the other cultural background was tested to diminish training or learning effects, in this case, all participants have three training sessions (pre-training, the basic virtual room, the other cultural background room). The result shows that participants have higher total presence level in their own cultural background than in the other cultural background (MD=2.78, t(17)=2.03, p=.059), the result is not statistically significant. However, there is a tendency to have a statistically significant effect (effect size r=.442). This result indicates that culture can affect total presence level, participants will have a higher total presence level.

The simulator sickness questionnaire (SSQ) was used to measure and score simulator sickness level every time immediately after participants finished the LEGO sorting task. The total simulator sickness score is the highest in the Basic virtual room, total simulator sickness score in the Asian-style virtual room (MD=61.50, SD =193.75; t(18)=1.38, p= .183) and in the Western-style virtual room (MD=53.32, SD=175.04; t(19)=1.36, p=.189) are both lower than in the Basic virtual room. The results show that background familiarity can affect total simulator sickness score, participants would feel less simulator sickness in a more familiar virtual workspace. The results of this study are not statistically significant. As for the effect of culture on total simulator sickness score, results show that Western participants have higher total simulator sickness score than Asian participants (MD=2.90, t(17)=.074, p=.94) in

Asian-style virtual room and lower score than Asian participants (MD=-17.16, t(17)=-.30, p=.77) in the Western-style virtual room. For all participants, total simulator sickness score is lower in their own background than the other background (MD=-6.26, SD=79.34), the result is also not statistically significant in this study (t(16)=-.33, p=.749).

4. Discussion and conclusion

In this study, the effects of background familiarity and culture on presence and simulator sickness level in a simulated workspace are investigated to provide advice for future simulated workspace design. The results showed that the participants generally have a higher presence level and lower simulator sickness level in a simulated workspace with higher background familiarity and a simulated workspace with their own cultural background. Increasing background familiarity scale also increased the richness of the virtual environment, which may cause some side effects such as a high simulator sickness level. More experiments are needed to investigate the interaction effects between background familiarity and background richness on presence and simulator sickness levels. Designers need to consider both background familiarity and background richness, and the cultural characteristics of users when designing a simulated workspace.

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