The Effects of Physical Fidelity in VR Simulation on Task Loads

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Abstract

The VR-based immersive learning environment is considered to increase the efficiency of the learning platform for SBL. This study which witnessed the participation of 36 students aimed to determine the effects of physical fidelity in VR training simulation on task load. It investigated three types of VR controllers to measure task loads. The outcome variable was participants' perceived task load (ten dimensions of workload. The results indicated that the level of physical fidelity of the VR controller affected the perceived task load. However, the use of a high-fidelity controller made users' perceived task load significantly lower than other controllers. This study provides valuable insights into adjusting task load and increasing task performance within the VR training simulations using the physical fidelity of VR.

Keywords: physical fidelity, simulation-based learning, task load, VR controller, VR simulation,

Introduction

Simulation-based learning (SBL) is an effective method for training (Harris et al., 2021). In this learning method, learners are provided specific situated learning experiences, and learners practice in authentic learning context environments to experience the concrete learning environment. The properties of VR, which provides realistic and immersive experiences, have made VR a perfect learning simulation for training, and are now widely used in various training such as military, aircraft, and surgery (Zhang, 2017).

In VR training simulations, the degrees of similarity to the real world is known to affect learning outcomes. In particular, SBL requires an effective transition to real-world performances, which is why VR learning environments should accurately represent the real-world skills and performance trying to train (Gray 2019). As VR aims to provide high-fidelity experiences similar to the real world, we commonly use fidelity to explicate the quality of simulation that contributes to training success (Al Jundi & Tanbur, 2022). High-fidelity simulations can provide more immersive experiences and transfer learned experiences into the real world. Therefore, more attention should be paid to the faithful implementation of the user's sensory perception from real training to develop practical VR training simulations. The purpose of this study was to determine how levels of physical fidelity of VR controllers influence users' task load in the VR training simulation.

Research Design & Methods

To better understand the relationship between physical fidelity and task performance, we conducted a study of three different levels of physical fidelity of VR controllers in a training simulation for drilling training. In this study, VR controllers were developed to reflect the real drill machine and divided into three levels of how much implement the real tool faithfully (high: weight + grip, mid: grip, low: only controller).

Thirty-six healthy college students participated in the present study (aged from 19 to 26, M=22.30, SD=1.81; 36 male participants). The VR driving screw task was developed using the Unity 3D game engine. Participants were instructed to drive the screw vertically correctly as possible. When the screw and controller made contact, audio feedback (drill sound) and haptic feedback (vibration) was provided. The dependent variables included participants' perceived task load (ten dimensions of workload: mental load, physical load, temporal load, frustration, complexity, stress, distractions, perceptual strain, task control, and presence). We explored the task load of the training using a self-report measure of task load, the SIM-TLX to address aspects of the physical fidelity of VR controllers (Harris et al., 2020). The participants utilized all the types of controllers in a counterbalanced order to account for order effects. Each participant experienced the simulation for approximately 10 min.

Results

A one-way repeated measures MANOVA was run to test whether there was an overall difference in task load (as measured by the SIM-TLX) among VR controllers. There was an overall effect of factor, $F (1, 20) = 2.14$, $p = .006$, Wilks's lambda= 0.55. Follow-up contrasts showed key differences in only two constructs (complexity and perceptual strain) of the ten sub-constructs. In the complexity, the mid-fidelity controller was the lowest of the other conditions, whereas, in the perceptual strain, the mid-fidelity controller was higher than the high-fidelity controller ($p = .039$), and the low fidelity controller was higher than the mid-fidelity controller ($p = .017$). All the other comparisons were non-significant (p's > .05).

Discussion

Even though research has extolled the benefits of high-fidelity experiences in VR (Al Jundi & Tanbur, 2022), research on the task load from the level of physical fidelity of VR controllers remains sparse. Effective operation using the VR controllers is required in simulation for the field of VR simulation training to progress (Harris et al., 2021). Consequently, we aimed to apply physical fidelity levels in testing the task load of VR controllers. A self-report questionnaire was used to assess whether the task loads of the VR task differed among the level of physical fidelity of VR controllers. After accounting for follow-up tests, only two sub-scales, namely the degree of complexity and perceptual strain were found to be significantly different among the controllers. Firstly, a VR controller does not necessarily need to faithfully reflect the weight of a real tool. Only providing the exact sensory grip, the perceived complexity of the task was the lowest. Second, using a generic VR controller was found to augment the perceptual strain. The higher the physical fidelity of the real drill machine, the lower the perceptual strain. This study's results show that the VR controller's physical fidelity affects the task load.

Conclusion

In this study, we aimed to test the task load of a VR simulation of drilling skills by applying the VR controllers' physical fidelity levels. This study provides valuable insights into adjusting task load and increasing task performance within the VR training simulations using the physical fidelity of VR. According to the assessment of construct validity, the VR controllers' physical fidelity was an effect on the perceived task load. The perceived task load showed differences in the levels of physical fidelity of the VR controllers. Nevertheless, this does not mean that the levels of physical fidelity are fully validated. Therefore, to determine whether the simulation elicits realistic training performance, further work is still required, such as assessing task performance through task completion time or inaccuracy time.

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