

The Effect of the Hand-tracking on University Students' Virtual Presence, Cognitive Load, and Spatial Ability in Virtual Reality Learning Environment

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This study aims to create a learning environment equivalent to real animal dissection by employing a 3D virtual reality (VR) simulation in a metaverse-based anatomical experiment. With the increasing flexibility of hand-tracking manipulation in VR, it is essential to understand how manipulating 3D objects in science simulations impacts students' cognitive load, virtual presence, and spatial ability. Therefore, this research examines hand-tracking's effects on college students' virtual presence, cognitive load, and spatial ability. A pre-posttest control group design will be applied to approximately 40 right-handed college students. All participants will engage in HMD-wearing learning within a metaverse platform for validation purposes. Each dependent variable will be measured using surveys and brainwaves, with one-way multivariate analysis of variance (MANOVA) in SPSS and machine learning techniques. This research could contribute to the development of more effective educational experiences by identifying the factors that positively or negatively influence virtual presence, cognitive load, and spatial ability.

Keywords: Virtual Reality, Metaverse, Virtual presence, Cognitive load, Spatial ability

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1. Necessity and purpose of the study

Recently, anatomical practice is being conducted using 3D software or animal models as an alternative to reducing animal testing, and there are reports that it is preferable to actual anatomical practice and has a better learning effect (Lalley et al., 2010; Elmalı, 2022). As such, there have been cases of applying monitor-based virtual reality in the past in relation to anatomy, and its effectiveness has been proven (Lee & Wong, 2014).

Virtual reality is increasing in use in educational settings (Hodgson et al., 2019). The reason is that it is possible to repeatedly master it in a safe environment and also experience an environment or situation that is difficult to use in traditional teaching methods (Larsen et al., 2012; Bailenson et al., 2018). Immersion is important to feel real-life experiences in virtual reality (Hamilton et al., 2021). HMD is more effective than monitoring to increase immersion in virtual reality (Krokos, Plaisant, & Varshney, 2019; Hamilton et al., 2021). In addition, with the development of technology, its utility has been proven in medical education in immersive virtual reality using HMD (Xu, Mangina, & Campbell, 2021).

When a user uses HMD in virtual reality, interaction with objects in virtual reality disconnected from the outside can be achieved through hand tracking technology along with controller equipment. In the past, controller equipment was primarily a major means of interaction in virtual reality environments, but recently, hand tracking is available with advances in technology (Hamed, Perkis & Möller, 2021). Controller equipment is essential in virtual reality, but cannot be applied in real life, and in the case of hand tracking, easy perception is possible because it is based on a human body (Doerner et al., 2022). In addition, since hand tracking can expect intuitive and natural interactions, we expected a lower cognitive load but we observed that the controller equipment provided better ease of use than hand-tracking and reduced cognitive load (Hamed et al., 2021).

This diversification of manipulation and interaction is a technology that can be used in Extended Reality in the future. However, it is expected that there will be a difference between hand tracking, which is shaped like an actual hand but does not have a haptic response, and operation and interaction using a controller that is sophisticated and haptic. In addition, there are several factors to consider in the learning environment using HMD. First, there is a virtual presence that will affect involvement by providing realness in virtual reality. Second, there is an EEG related to cognitive load. If you check how there will be a difference under

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these conditions, it will be helpful in designing learning in virtual reality.

The purpose of this study is to investigate the effect of hand-tracking on University Students' virtual presence, cognitive load, and spatial ability. To this end, three research questions were set up.

R1. What is the effect of hand-tracking on university students' virtual presence in a virtual reality environment?

R2. What is the effect of hand-tracking on university students' cognitive load in a virtual reality environment?

R3. What is the effect of hand-tracking on university students' spatial ability in a virtual reality environment?

Theological Background

1. Virtual presence and VR

Virtual presence refers to the perception of an individual who feels as if an environment composed of a virtual environment exists in real life (Selzer, Gazcon, Larrea, 2019). The higher the virtual presence, the more positive learning effects can be expected (Schrader & Bastiaens, 2012). In particular, the learner's immersion affects the virtual reality. In addition, the greater the stimulation of a person's five senses by the media's attributes, the easier it is to create a virtual sense of reality. In this context, immersive virtual reality such as HMD can stimulate more of a person's five senses, so you can feel a great sense can be greatly felt.

2. Spatial ability and VR

Spatial ability refers to an important function in solving the problem of manipulating and processing spatial information (Lajoie, 2008; Ramful, Lowrie, & Logan, 2017). Spatial ability involves working with mental or, more specifically, spatial imagery (Hegarty, 2010). Giving control and active learning to learners with high spatial capabilities in VR environments, performance with high levels of perceived learning and satisfaction is promoted (Lee, Wong, & Fung, 2010). Learners with low spatial ability can conduct more positive learning in a VR environment (Lee & Wong, 2014). Therefore, since the VR environment can be applied differently according to its level in relation to spatial capability, it is necessary to explain through research problems.

3. Cognitive load theory

Cognitive load theory is a basic theory used to explain the cognitive process in which learners learn (Sweller, van Merriënboer, & Paas, 2019). For instructional design, it should be possible to adjust the learning processing capacity to reduce the load of the working memory and accommodate limited capacity (Sweller, Ayres, & Kalyuga, 2011). Cognitive load refers to the total amount of mental activity assigned to working memory when processing information (Swaller et al., 2019).

There are three types of cognitive load (Intrinsic, Extraneous, and Germane). Intrinsic cognitive load is determined as a result of the complexity or element interaction of the learning task. Learning tasks become more complex as the Intrinsic cognitive load increases. However, because the learner's prior knowledge also serves to determine the Intrinsic cognitive load, it may not be a feature of educational content (Park, Korbach, & Brünken, 2015).

Exogenous cognitive load is a cognitive load that causes learners to treat interaction elements as unnecessary increases and is the result of inappropriate instructional design. The Germane cognitive load is the load that appears in the process of forming and adjusting the mental structure. It refers to a mental effort to integrate new knowledge into the existing knowledge system.

According to the cognitive learning theory, since the capacity of working memory is limited, learning can be suppressed if the total cognitive load calculated in the learning process exceeds the learner's learning ability (Sweller et al., 2019). For effective learning, the total cognitive load should be placed within the working memory limits by maximizing intrinsic cognitive load and lowering exogenous cognitive load (Sweller, 2010).

In relation to cognitive load and virtual reality, the increase in virtual reality enhances cognitive load (Schrader & Bastiaens, 2012).

This measurement of cognitive load can be measured in various ways (Mutlu-Bayraktar, Cosgun, & Altan, 2019). There are subjective or objective measurement methods, such as self-report questionnaires, or objective observation, physiological status, or performance (Brunken, Plass, & Leutner, 2003). Physiological measurements are emerging due to problems with the reliability or validity of subjective measurement methods, and eye tracking and EEG are mainly used (Mutlu-Bayraktar et al., 2019).

Method

1. Participants

The study will recruit 40 right-handed male university students aged 19 to under 25. The reason for recruiting single-gender and right-handed students is to minimize the impact of gender or dominant loss. Using IRB-approved recruitment documents, the research subjects will be recruited through the website of Chonnam National University, where many research subjects can be accessed. Chonnam National University, which will recruit research subjects, is located in Gwangju, South Korea, and is a national flagship university.

2. Experiment and learning content

a. Covariant – virtual presence, prior anatomical knowledge, spatial ability

The covariance of this study is the level of virtual reality perceived by VR devices. As for the question, Yang & Ryu's (2019) virtual reality measurement item was used. This is to measure the virtual reality perceived by VR devices before being put into the experiment. In addition, prior understanding of anatomical knowledge related to biology was measured. The space capability test will use Purdue Space Visualization Examination (Revise PSVT:R) (Yoon, 2011; Park, 2012).

b. Independent Variable -Differences in the type of control (non-control vs with hand-tracking)

The difference in operation means the distinction between non-control and hand-tracking use. In this study, one condition is that the hand-tracking interactions with 3D objects provided by HMD are used by different operations [Figure 1].

Figure 1. Example of hand-tracking manipulation of 3D objects



3. Design

This study will use the Pretest-Posttest Control Group Design. To compare the differences between groups a control group and a non-treatment group (viewing learning materials after wearing HMD) is established. The treatment group manipulates the 3D frog model through hand-tracking along with viewing learning materials after wearing HMD.

4. Measurement

a. Virtual presence

Virtual presence is the degree to which virtual reality users perceive the virtual reality environment as real life. The scale to be used in this study is a virtual presence measurement question by Yang and Ryu (2019), and a total of 15 questions, using a 7-point scale. The sub-factors are in involvement (5 questions), spatial presence (5 questions), and realness (5 questions), and the internal consistency indices of each sub-factor of the original scale are .88-.95, .72-.85, and .85-.87, in order.

b. Cognitive load

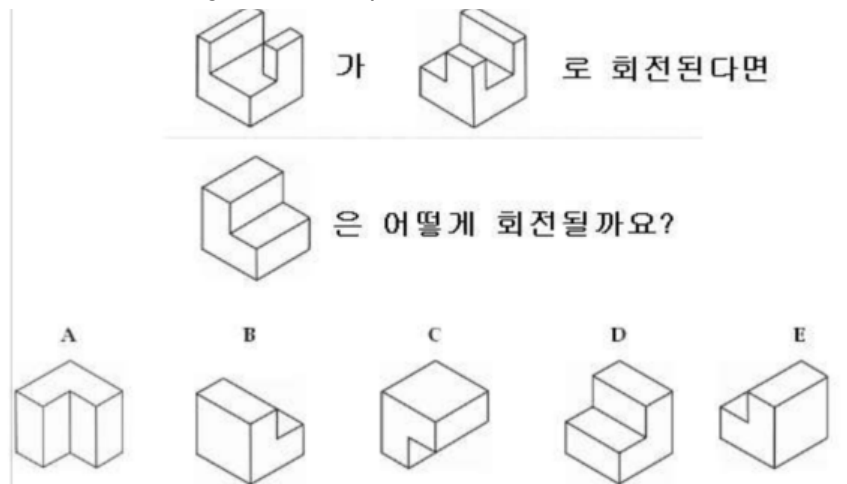
To measure cognitive load, Enobio EEG 32 will be used. In particular, it is intended to verify the cognitive load occurring in the same part by comparing the EEG signal generated while using a controller or hand-tracking with the EEG signal in the process of testing spatial capability.

Enobio 32 is a Neuroelectric product that captures high-density EEG signals. It has an integrated user interface and a spectrum program, and can 3D visualize spectrum data in real-time. Enobio 32 was attached to the participant's head to collect EEG signals. The referenced EEG data was transmitted wirelessly to the computer for further analysis.

c. Spatial ability

Revised PSVT:R will be used to measure spuriousness and will be randomly placed to prevent sequential effects. It is a non-verbal test that checks the degree of rotation of a three-dimensional figure with a total of 30 questions. Among the questions, 13 are symmetrical figure questions and 17 are asymmetrical question questions, and for a response, the model rotated in the same way as the view must be found as a five-point multiple [Figure 2].

Figure 2. View questions in Revise PSVT:R



d. The anatomical knowledge

The anatomical knowledge used in the post-test will present a different order from the pre-test. The test questions will be based on education on frog dissection. Multiple choice questions will be asked about the name, structure, and arrangement of the organ. This inspection will be reviewed by an expert after production for content validity. Through preliminary research, the final question will be selected by measuring the difficulty, discrimination, and internal consistency of anatomical knowledge.

5. Experimental procedure

a. Participants arrive

Participants arrive at a designated experimental site according to the guidance of the researcher. It is expected that the number of participants will be somewhat small within 40, and the imbalance between the control group and the treatment group will be corrected in advance using block randomization. The order of assignment will use a computer program.

b. Pre-training

Pre-training on how to move or operate will be conducted in about 5 minutes by wearing a VR device and connecting the metaverse platform. The metaverse platform to be used in this study is VIVE Sync, and it is mainly specialized in meetings and collaboration. The most characteristic part is that it is possible to

upload files of various types (documents, images, and 3D files), and support HMD's hand-tracking function. The HMD device will use VIVE Focus.

VIVE Focus 3 provides 2448×2448 pixel resolution and provides a viewing angle of up to 120°. Four tracking cameras are installed to implement standing and sitting tracking, and a room-scale environment with a maximum space of 10m×10m. In addition to the operation using the controller, hand-tracking is supported and can be implemented without a separate controller. All groups will sit and use controllers or hand-tracking without moving.

c. Pre-test

The participants will stop wearing VR devices for a while and a survey on virtual presence, anatomical knowledge, and spatial ability will be conducted for about 20 minutes.

d. Experiment

Participants will participate in the experiment by sitting on chairs in designated spaces for actual measurements. The researcher will guide the experiment and supervise all the experiments. Humidity or temperature will be kept constant during the experiment, and external noise will be blocked. During the experiment, participants will refrain from speaking as much as possible to prevent any noise from entering the brain waves.

Participants will wear EEG measurement equipment and HMD, access the metaverse platform, and take a break while listening to the pre-prepared neutral stimulation image and comfortable music for about two minutes. Participants will watch a brief study on frog dissection. The learning data, a three-dimensional implementation of the anatomical image of the frog, will be played in about 2 minutes. The control group will listen to the neutral stimulus image and comfortable music that they first heard for about two minutes after viewing the learning materials, and then take off the HMD to conduct the survey.

The treatment group according to the type of control, like the control group, will directly manipulate the 3D frog anatomy image learned after watching the rest time of 2 minutes and the learning material of 2 minutes. Three-dimensional frog anatomy images will be downloaded from the Unity Asset store [Figure 3]. It will take about two minutes to operate it directly using an actual controller or hand-tracking, and after listening to the neutral stimulus image and comfortable music that it heard for the first time for about two minutes, the HMD will be taken off and a survey will be conducted.

e. Post-test

Both the control group and the treatment group will continue to wear the EEG until they have completed their spatial capabilities in the survey. In the case of presence and anatomical knowledge and spatial ability, a survey will be conducted after the experiment is completed to receive answers. It will take about 20 minutes.

Figure 3. 3D frog anatomy image



6. Analysis method

In order to analyze the results of this study, one-way multivariate variance analysis and measurement will be conducted. The dependent variables according to the difference in the operation method, which are independent variables, are virtual presence and spatial ability. Virtual presence and spatial ability will be multivariate analyses. In the case of EEG, the collected data will be preprocessed and made into a predictive model through training data and verification data through machine learning. In other words, a model that predicts under what conditions the cognitive load has occurred will be produced and a comparison between groups will be conducted. SPSS 24.0 is used for data analysis, and the statistical significance level will be set to .05.

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