Comparing the Workload of Joysticks, Buttons, and Hand Gestures in a Virtual Reality Environment

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1 Introduction

As virtual reality (VR) becomes increasingly embedded into modern applications from gaming and education to medical simulation and remote collaboration, designers face the challenge of building intuitive and user-friendly interfaces. At the heart of these immersive experiences are input devices: the bridge between the user's intent and virtual action. While modern VR systems offer a range of control methods, two of the most common are joysticks and buttons. These input modalities, though functionally similar, may impose very different cognitive and physical demands on the users.

Consider a user who navigates a simple path in a VR environment. The experience may seem straightforward, but subtle differences in the interaction technique, such as pressing direction buttons versus tilting a joystick, can alter how the task feels. Is the user mentally straining? What button does what? Is their thumb fatigued from repetitive pressing? Does the joystick offer smoother control that feels more natural? These nuances in interface design can ultimately affect user satisfaction, efficiency, and even long-term engagement.

In this study, we investigate how the interaction technique influences the perceived workload in a VR task. Specifically, we compare three input modalities, joysticks, buttons, and hand gestures, by analyzing user responses to a navigation task implemented in Unity on a Meta Quest 3. Participants are asked to control a boat through a simple path using either the joysticks or the buttons on the VR controllers, or by making pre-defined gestures with their hands. We measure perceived workload using the NASA Task Load Index (NASA-TLX) [4] [5], a well-established instrument that assesses mental demand, physical demand, temporal demand, perceived performance, effort, and frustration.

Our research builds on prior studies that explore interface usability and cognitive load in human-computer interaction (HCI), extending the analysis into the immersive domain of virtual reality. By comparing subjective

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workload ratings across different control schemes, we aim to provide insights that can guide the design of more accessible and efficient multimodal interfaces in a virtual environment.

2 Related Works

2.1 Comparison of Input Modalities

Ways to interact with a virtual environment will become more prevalent in the coming years. Studies already being done in healthcare are laying the groundwork for virtual training modules. In "A comparison of input devices for precise interaction tasks in VR-based surgical planning and training“, input devices for common interaction tasks were compared. The input devices were studied and compared with respect to their suitability for performing precise VR interaction tasks. These devices were standard VR controllers, a pen-like VR tool, data gloves, and a real craniotome. The input devices were quantitatively compared to measure their performance based on different measurements [1].

In addition to differences in performance, comparable input modalities have also been found to have varying workloads. Rupp et al. [11] compared the Xbox controller and the joystick using both the NASA Task Load Index and the system usability scale. The Xbox controller was found to be slightly more usable with a lower workload. Sadasivan et al. [12] compared the use of gamepads and joysticks for NDI training simulations using a virtual borescope. The gamepad was found to perform better than the joystick under the specified parameters of their study.

Neumann and Durlach [8] found that joysticks provided smoother user interaction and lower workload ratings in high-precision tasks, whereas button-based controls required more user attention and induced higher cognitive strain. Additionally, prior experience with gaming controllers significantly influenced performance, as seen in studies that examined the effects of familiarity on task efficiency [8].

Zhao et al. [13] compared three hand gestures with a gamepad interface for locomotion tasks in virtual environments. Two of the hand gestures showed user preference similar to that of the gamepad interface, and the remaining hand gesture received lower scores in most measurements.

Our research builds on previous findings by comparing the usability and workload impact of joystick-based and button-based interaction in a VR task, unlike previous studies, which focused on 2D tasks.

2.2 Effect of Virtual Reality on Workload

Measuring the workload of input modalities in virtual reality raises the question of how extended reality affects workload compared to 2D applications. Studies on the effects of presence, immersion, and flow in virtual reality found that virtual reality simulations resulted in a lower perceived workload but did not have any measurable effect on performance [7].

Our study investigates the workload of specific input modalities in virtual reality navigation, where understanding perception and spatial reasoning can introduce new workload considerations.

VR offers a compelling method for studying cognitive load in dynamic environments. Traditionally, cognitive load has been investigated in static tasks, but with VR it opens the door to replicating complex, real-life scenarios while maintaining experimental control. A study comparing real-life and VR navigation in a train station found no significant difference in workload indicators-measure through electrodermal activity (EDA), NASA-TLX, and memory recognition-between the two environments [2].

Novice users consistently exhibited higher cognitive load than experts in both VR and real-life, reinforcing that prior experience significantly modulates cognitive strain during navigation tasks. This aligns with our current understanding in which users unfamiliar with VR or interaction modalities may experience elevated perceived workload, regardless of input devices.

Additionally, the study emphasized the need to consider multiple dimensions of workload: physiology, behavior, and subjectivity. Our use of NASA-TLX captures subjective load, but future studies could integrate physiological signals such as EDA or heart rate variability to provide a more comprehensive understanding of workload in VR navigation tasks. Together, these insights reinforce the validity of VR as a tool for evaluating cognitive load, particularly in navigation tasks. They also support the incorporation of using mixed-method approaches in future workload research.

2.3 Measurements of Workload

Sandra G. Hart's research on NASA-TLX [4] provides an extensive insight into how workload is measured across different human-computer interactions, which also includes virtual reality environments. The NASA-TLX has been widely used in various fields, including aviation and remote vehicle operations, to assess the mental and physical workload differences between interface designs.

NASA-TLX can be measured using either a paper-based form or a digital version. Noyes compared the workload of completing each version of the form and found that completing the digital version had a higher associated workload [9].

3 Methodology

3.1 Participants

We will select a total of eight participants on a volunteer basis. To ensure ethical compliance and informed consent, all individuals will be at least 18 years of age at the time of enrollment. The participant pool will consist of individuals with varying degrees of prior experience using virtual reality (VR) technology. This diversity in experience will allow for a more comprehensive assessment of the user-interaction experience.

3.2 Apparatus

Using Unity, we developed software to deliver the virtual reality experience. The software is composed of four separate scenes. Each scene contains the same objective conveyed to the users by text on the screen. The users control a boat that they need to navigate across a simple path to the end of a stream. For hardware, a Meta Quest 3 will be used. This includes the Virtual Reality headset and controllers. The two controllers have a joystick and two buttons each. We will use a computer to mirror the virtual reality content so we can monitor user interaction and activity.

3.3 Procedure

The participants will be given instructions audibly and visually describing the controls they will be using to navigate four different scenes. This will be before they put on the headset, so they can get an understanding of the controls before using them. Throughout the use of the VR headset, the users will remain standing.

The first scene is the control, where we measure the user's baseline in Virtual Reality. In this scene, a boat will move on its own down a stream so the users can get a visual of the objective, and we can measure how they feel in Virtual Reality environments generally. This will help us filter out potential outliers that may lead to discomfort or disorientation in Virtual Reality independently of the interaction techniques.

In the second scene, the users will have access to the A, B, and X, Y buttons on the left and right controllers to move the boat. X and Y will control up and down, and the A and B buttons will control left and right. Similarly, in the third scene, the users will use the left joystick to navigate the path and get the boat down the stream.

In the fourth scene, users will utilize hand gestures to move the boat. This involves using the thumbs up on either hand for lateral direction, and making a fist with the left hand to move the boat forward.

The following task will be triggered automatically when the users complete reaching the end of the stream for the current task. This successful completion will be confirmed with a pop sound so that the user knows that they have finished.

After each of the four scenes, we will survey the user's experience with each of the tasks. To do this, we will administer a questionnaire to assess the NASA Task Load Index. This will measure user perspectives by comparing the mental demand, physical demand, pace, success, difficulty, and distress. In addition, we will also measure the amount of time each task takes the user.

3.4 Design

The independent variable is the input method used to interact with the content. We chose to test three input methods for this, which were the usage of the joystick, buttons, or hands. The buttons represent four discrete movement choices to move the ball, whereas the joystick allows for continuous 360-degree movement. The dependent variable is the perceived workload, as measured by the NASA Task Load Index. We will use the NASA Task Load Index measured after the first scene as our baseline control.

The total number of trials will be 32 (=8 participants x 4 input methods).

4 Limitations

While this study provides valuable insights into the perceived workload differences between interacting using hands, a joystick, or buttons in VR, several limitations must be acknowledged.

First, the reliance on the NASA Task Load Index (NASA-TLX) introduces potential subjectivity in the data. Although widely used, this self-reporting instrument is influenced by user expectations, mood, and interpretation of the scales. As discussed by Hassenzahl [6], usability metrics alone can not fully capture user experience (UX), and subjective tools may oversimplify the complexity of the users' perception.

Second, our study was conducted in a controlled environment, which may reduce ecological validity. While VR allows for precise replication and experimental control, the contextual and emotional nuances of real-world use are often difficult to simulate [3]. This limitation is very important when considering that the UX is shaped not only by interaction quality, but also by social, cultural, and environmental factors.

Third, our sample size was limited to eight participants, which is sufficient for an initial evaluation, but limits the generalizability of the results. Furthermore, participants' prior familiarity with VR or gaming controllers may have biased their perception of each input method. Novelty effects may also skew workload ratings for users unfamiliar with VR devices, as they may be too focused on trying to adjust to their environment rather than handling the given task [10].

Lastly, our evaluation captures only post-task workload. Real-time physiological data such as heart rate, facial expression, or posture could provide deeper insights into moment-to-moment cognitive and emotional responses, but were outside the scope of this study.

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