HOCHSCHULE DER MEDIEN

Bachelor's thesis

Computer Science and Media degree program

The Impact of Exclusive Head Movements (6DoF) on Navigation Efficiency, Accuracy, and Accessibility for Users with Physical Disabilities in Virtual Environments

Submitted by

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on July 14, 2025

at Stuttgart Media University

in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.)

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Acknowledgments

I would like to thank all my professors, especially my tutor, Ansgar Gerlicher, from University of Media (Hochschule der Medien), for his helpful feedback during the refinement of this project and for always being accessible and supportive during our communication. I am also thankful to my external co-supervisor, Jahn Daßler, from Mercedes-Benz, for his valuable insights and guidance, and for helping me connect academic theory with real industry needs throughout the development process. My sincere thanks go to University of Media for offering a practical, interdisciplinary learning environment that truly matched my interests and learning style, especially through the flexibility in elective course choices. I am deeply grateful to my husband, Andreas Kreitschmann, for being by my side and supporting me through every step of this journey. I also thank my mother, Joseli Casimiro da Silva, who, even from Brazil, always prioritized my education and played a key role in everything I've achieved. Lastly, I would like to thank Cajú, my little dog, who has been my emotional support during most of my academic journey.

Abstract - EN

This study explores the development and evaluation of NavHead, a virtual reality interface controlled solely by head movements, aiming to provide an inclusive user experience for people with and without disabilities. By analyzing usability, accuracy, and accessibility, the results showed that head-based navigation is generally comfortable and understandable, though not entirely intuitive. Among the tested selection methods, the blow technique was preferred over the time-based pause, offering faster and more efficient interactions. Despite technical and logistical limitations, especially regarding testing with participants with disabilities, the findings suggest that head movement interfaces can be a viable and meaningful alternative to traditional VR controllers. This work highlights the importance of designing customizable and inclusive interfaces from the outset, expanding the possibilities of VR use in assistive technology, education, and rehabilitation.

Keywords: Virtual Reality, Accessibility, Head-based Interaction, Inclusive Design, Assistive Technology, Usability, NavHead, Human-Computer Interaction

Kurzfassung - DE

Diese Studie untersucht die Entwicklung und Bewertung von NavHead, einer Virtual-Reality-Schnittstelle, die ausschließlich über Kopfbewegungen gesteuert wird, mit dem Ziel, ein inklusives Nutzungserlebnis für Menschen mit und ohne Behinderungen zu ermöglichen. Durch die Analyse von Benutzerfreundlichkeit, Genauigkeit und Zugänglichkeit zeigte sich, dass die Navigation per Kopfbewegung im Allgemeinen als komfortabel und verständlich empfunden wird, obwohl sie nicht vollständig intuitiv ist. Von den getesteten Auswahlmethoden wurde die „Pusten"-Technik gegenüber der zeitbasierten Pause bevorzugt, da sie schnellere und effizientere Interaktionen ermöglichte. Trotz technischer und logistischer Einschränkungen, insbesondere im Hinblick auf Tests mit behinderten Teilnehmern, legen die Ergebnisse nahe, dass kopfgestützte Schnittstellen eine sinnvolle Alternative zu herkömmlichen VR-Controllern darstellen können. Diese Arbeit unterstreicht die Bedeutung einer anpassbaren und inklusiven Gestaltung von VR-Schnittstellen von Anfang an, um das Anwendungsspektrum in Bereichen wie unterstützender Technologie, Bildung und Rehabilitation zu erweitern.

Keywords: Virtuelle Realität, Barrierefreiheit, Kopfgestützte Interaktion, Inklusives Design, Assistive Technologie, Benutzerfreundlichkeit, NavHead, Mensch-Computer-Interaktion

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Acronyms

AI	Artificial Intelligence
AR	Augmented Reality
APP	Application
BCI	Brain-Computer Interface
CSQ-VR	Cybersickness in Virtual Reality Questionnaire
DoF	Degrees of Freedom
EEG	Electroencephalogram
EOG	ElectroOculogram
EU	European Union
GB	Gigabyte
GmbH	Gesellschaft mit beschränkter Haftung
GPU	Graphics Processing Unit
HDM[1]	Head-Mounted Displays
HDM[2]	Hochschule der Medien
HTC	High Tech Computer Corporation
IDE	Integrated Development Environment
KFV	Körperbehinderten-Verein Stuttgart e.V.
MR	Mixed Reality
NASA-TLX	NASA Task Load Index
OHF	One-Handed Flying
PC	Personal Computer
PCVR	Personal Computer - Based Virtual Reality
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RAM	Random-Access Memory
SoC	System on a Chip
SSQ	Simulator Sickness Questionnaire
SUS	System Usability Scale

THF	Two-Handed Flying
TP	Teleportation
UEQ	User Experience Questionnaire
USB-C	Universal Serial Bus Type-C
USA	United States of America
VR	Virtual Reality
WIM	Worlds-in-Miniature
XR	Extended Reality

1. Introduction

Virtual reality glasses are a technology that is changing the way people interact with virtual environments. Whether through games, product experiencing, or even for the accessibility of people with disabilities. A virtual environment can provide an experience that, to the human brain, may feel real. Through this, the body perceives it as a real experience, relying primarily on vision and hearing senses.

1.1 Motivation

Intuitive systems are of a higher importance for the user experience in the virtual environment. However, despite the effectiveness of existing systems and accessories for the use of virtual reality applications, some possibilities beyond the obvious are necessary for the development of applications that can include people and improve daily activities such as multitasking, in the scenario of the routine use of virtual reality glasses.

Comprehending these aspects is important not only to meet market demands, making this technology more accessible to people without disabilities - for example, individuals with occupied hands who need to perform tasks in a virtual environment - but also to assist people with limited mobility due to disabilities in interacting with everyday technologies. Thus, they may use virtual reality glasses to engage with applications, regardless of their purpose.

1.2 Research Question

The traditional input methods for utilizing a Virtual Reality device are usually controllers and hand trackers, but these methods can offer some limitations, considering their complexity and accessibility issues for some users. As VR technology becomes more embedded in daily routines - from education and remote work, to therapy and leisure - ensuring that these systems are accessible to all users is important.

Therefore, the idea of an application that can be used only with head movements works as an experiment to find alternatives to these limitations. This research proposes the exploration of exclusive head movement as a navigation method, offering a hands-free alternative aimed at improving accessibility and reducing interaction complexity in virtual environments.

This leads to the central research question: How do exclusive head movements (6DoF) impact navigation efficiency, accuracy, and accessibility for users with physical disabilities in virtual environments?

1.3 Objective of the Work

This study, titled: “*The Impact of Exclusive Head Movements (6DoF) on Navigation Efficiency, Accuracy, and Accessibility for Users with Physical Disabilities in Virtual Environments”* aims to analyze the potential of using head and neck movements as the sole input method in VR navigation.

This work does not seek to prove that current systems are outdated or bad, but rather seeks to create inclusion alternatives for handling virtual reality applications. Especially for individuals who experience limitations in upper-body mobility. To support this investigation, a prototype VR application called NavHead was developed using Unity, C# and Blender, enabling practical testing of head-based interactions in a controlled 3D environment.

The objective of this study is to assess the efficiency, effectiveness, and accessibility of head-only navigation in VR. In particular, the work examines how this input method can support users with physical disabilities while maintaining an intuitive and responsive interaction experience.

1.4 Structure of the Thesis

This thesis is organized in 11 chapters. The chapter 1 in the introduction, to present the goal and main topic of this research. The chapter 2 - State of the Art - presents a literature overview and technologies related to VR navigation. Specially considering different interaction concepts, like head-movement-based control and 6DoF limitations due to upper-body constraints. Additionally, it discusses usability and efficiency aspects in VR and introduces assistive technologies used in XR. Finally, it presents the Meta Quest 3 and its Touch Plus Controllers, and compares them with other headsets.

The chapter 3 is called Concept and objectives. It identifies gaps in current research and shows the need of the current research and proposed solution. It also aims to demonstrate why the NavHead application is relevant to this field. In the chapter 4 is the description of the NavHead application. It explains its functionality, internal architecture, and key design decisions. It also presents the current limitations and compares the approach with similar or existing solutions.

In the chapter 5 - Methodology - describes the norms of the user study. It describes the participant selection, the tasks used to evaluate the system, the hardware and software involved, and the variables that were measured. Ethical considerations are also addressed to ensure consistency and integrity in the research process. Chapter 6 - Demo Application and Pre-Study - It is important to show the results of the pre-test together with the changes needed for the final application and final test. Chapter 7 - Main Application and study results - refers to the information about the main data collected during the experiment. The results are used to evaluate the research hypotheses and to draw conclusions about the effectiveness and accessibility of head-movement-based interaction in VR.

Chapter 8 is the Discussion, where the research questions and hypotheses are revisited and discussed.It also discusses possible explanations and limitations of the outcomes. The chapter 9, called Conclusion and Outlook, is the final chapter. It summarizes the main findings of the thesis, reflects on the goals, and provides suggestions for future research or improvements to the NavHead application.

Finally, in chapter 10 there is the bibliography, where all cited literatures are located. And in chapter 11 - Attachment - the questionnaires used during the research is added, as other types of raw data, like asset images created on Blender and AI generated images.

2. State of the Art

2.1 VR navigation: methods and interaction concepts

Virtual reality creates an immersive 3D environment in which the user has the feeling of being inside a computer-generated world. In VR, the real world is replaced by the virtual environment, which is why it works with various senses of the human body, through virtual reality glasses, headsets, haptic gloves, controllers... Interaction takes place through the movement of the human body such as the head, hands, feet, or the body as a whole. In addition to VR, there are also other nomenclatures to encompass more types of immersive technologies. For example, XR (Extended Reality). XR incorporates VR, AR (Augmented Reality), which is the juxtaposition of virtual elements in real environments, without blocking the environment, and MR (Mixed Reality), where virtual objects interact with real objects, such as a virtual flower growing in a real clay pot in the environment (Hololight, 2023).

2.1.1 Alternative navigation paradigms in VR

In the virtual reality environment, there are various ways of moving around and handling objects. The user can, for example, walk around the artificial space, using a physical area available in the real world. One can also walk in the same place - Walking-in-Place - to simulate locomotion. Some gadgets help to manipulate objects, such as controllers, which can also be used for locomotion, using the teleportation mode (point to the location and move), or the Point-and-Move mode, which consists of betting and holding to move slowly towards the pointed location. Another gadget is a joystick that can be used to play video games. Besides that, there is the alternative of dealing with a miniature world, handling the virtual world by tracking one's hands using gestures. Gaze-directed, which is the use of the eyes to perform tasks is also another possibility in the VR navigation method. In addition, there are movements based on the brain-computer interface (BCI), which are movements carried out with inputs from the brain, but these are still in the testing phase.

A study focused on showing Big Data using virtual reality compared four VR navigation techniques: teleportation (TP), in which the user points to a destination point with the controller, confirms it and appears in the selected location. One-Handed Flying (OHF), which involves pointing the controller in a desired direction, the more the arm is stretched out, the faster the movement. Two-Handed Flying (THF), the user uses the controllers in both hands and draws an arrow between them that indicates the speed and direction of movement, and finally Worlds-in-Miniature (WIM), which uses a controller and a VIVE tracker[1] to hold a miniature graphic using the tracker and with the controller, the user can move a camera inside the miniature. After applying some tests to get the user to find dots of certain colors, this study came to the conclusion that THF is more effective for exploring large graphics, but it is the type of navigation that requires the most movement and is the most complicated to learn (Drogemulle *et al.*, 2020).

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[1] Accessory that enables wireless VR tracker, with accuracy and using 6 degrees of freedom (HTC, 2025). There are some models, but in the mentioned study the VRige application was used, using HTC Vive Pro-Head Mounted Display and HTC Vive controllers (Drogemuller *et al.*, 2020).

In this case, in the study mentioned above, it can be seen that there are various possibilities for navigating the world of VR, for different purposes. In addition, using the controllers and, consequently, the arms, is more intuitive, even if it requires more body movements. However, despite comparing the use of one hand, both hands and/or the tracker, none of the options focused on less intuitive body navigation methods. So the possibility of implementing new means of navigation for virtual reality environments becomes a challenge that could increase the possibilities of this technology, which is becoming increasingly accessible.

2.1.2 Head-Movement-Based interaction

Human head movements have three main bases. Neck Rotation, which turns the head from right to left around the central axis; Neck Flexion, which refers to tilting the head forward and backward; and Lateral Bending (Figure 1), which is the lateral tilt of the head according to the axis. A study on the response of the human head when hearing sounds even determined that there are physiological limits to movements, indicating that they can reach 70°, generally with an accuracy of +- 2 degrees (Gilman, Dirks and Hunt, 1979).

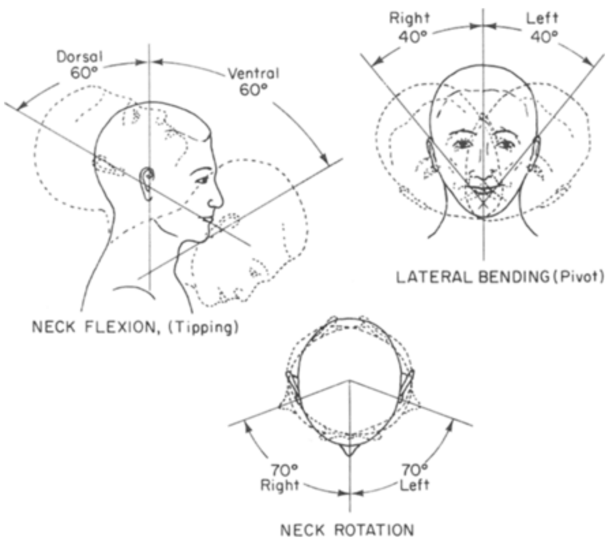


Figure 1: Head Rotation (Gilman, Dirks and Hunt, 1979)

In the article "Anatomy, Head and Neck, Neck Movements", Jung, Black, and Bhutta (2023) explain the anatomy of the head in detail. Indicating that the spine has 7 vertebrae (C1 to C7), in which C1 connects directly with the skull (Figure 2). C2 allows rotation (Neck Rotation) with the head and C3 to C7, are responsible for rotation and lateral inclination. In addition, the study indicates that the neck stabilizes the head in order to try to keep the eyes parallel to the ground, which is important for balance.

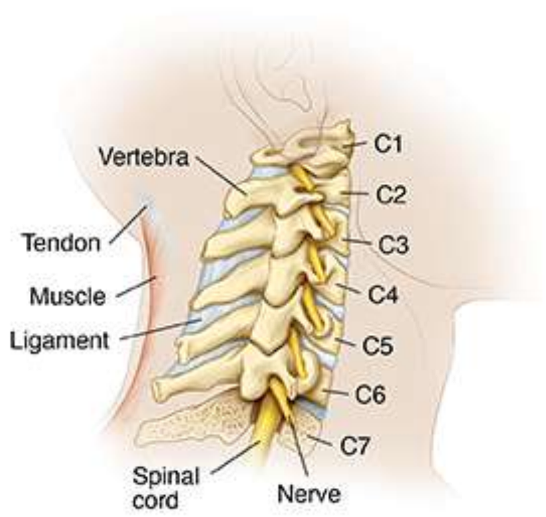


Figure 2: Vertebrae (Saint Luke's Health System, n.d.)

Considering the positions of the 7 vertebrae mentioned above, it is possible to infer one thing. That the movement of the head depends on the functioning of these vertebrae, and that injuries can limit the movement of this limb. Precise data on the number of people with physical disabilities who can only move from the shoulders up is not easy to come by, especially since data on this type of injury is general. In other words, a cervical injury (quadriplegia) usually occurs in the vertebrae below C3, meaning that people with C4 injuries are still able to preserve neck movements. However, the exact percentage of people with an X or Y vertebra injury, whether in Europe or the USA, is not specific.

Taking into account the inclusion of people with disabilities in technology applications, as well as the need to offer more control options for users who have their hands full, it is essential to develop interaction alternatives for virtual reality glasses that do not depend on manual use. Hands-free control systems are necessary to promote greater autonomy. There are already products designed, for example, to control wheelchairs without using hands, which gives users much more freedom. One example is Munevo Drive, developed by Munevo GmbH, a Wheelchair Control app for Smartglass.

Munevo Drive is a gadget that uses the head to control a wheelchair (Figure 3). The smart glass uses the Android system and takes the data for movement to the Munevo adapter, which converts these signals to direct the wheelchair. In addition, Munevo Drive can change wheelchair settings, take photos, and send messages in emergency situations. This app on the glasses can also be used to control a smart home smartphone or even a robotic arm (REHADAT, 2024a).

Figure 3: Munevo Drive (REHADAT, 2024a)

In addition to the above technology, there are other systems based exclusively on the use of the head to interact with wheelchairs. For example, the Moso Kinnsteuerung, is a piece of hardware consisting of a joystick and two buttons that can be moved using only the chin, and by connecting this hardware to an application, the user can move the wheelchair and also, configure the wheelchair's settings. Both indoors and outdoors (REHADAT, 2024b). Another option for handling an application, using only the head, is MyEcc. This is an eye control for a power wheelchair. Created by HomeBraceGermany GmbH, this gadget allows a person to control a power wheelchair using only the person’s eyes, in which the application makes the command by monitoring the “path” of the eyes, causing the chair to move in the desired direction. This even includes some safety systems, such as stopping the movement of the chair if the eye is no longer detected - for example if the user falls out of the chair - or if there is a strong light source on the sensors that blocks the user's command, or if the safety lock is activated if one of the connections/plugs is disconnected (REHADAT, 2024c).

Further on to another type of application control using solely the head, American researchers developed a system more than 10 years ago that allows paraplegics to control wheelchairs and computers using a tongue piercing, which generates commands according to its position detected by magnetic sensors. The article in

Spiegel Gesundheit (2013) presented the test with 11 paraplegics and 23 healthy people who learned to operate the system in just half an hour, performing tasks such as typing in numbers and crossing obstacles. The technology offers more autonomy and integration, while other innovations, such as electrodes in the brain, are also advancing to improve the lives of people with disabilities.

Stephen Hawking was an example of a person with severe movement disability who, through technology, was able to communicate and move around. The system used in his wheelchair was improved over time. But it consisted of an infrared sensor attached to his glasses that detected fine movements of his cheek muscles. The movement made with his cheek was used to trigger actions in his computer, and based on Stephen Hawking's input, the software developed by SwiftKey predicted the words and sentences to allow Prof. Hawking to communicate faster (Garcia, 2018). He would then pick the words and sentences, choosing the word while the cursor was passing by. Like Thomas said: “Stephen Hawking twitched his glasses when the moving cursor was over the word he wanted to say. If he missed it, he had to wait for the cursor to go around again.” (Thomas, 2018). The text would be sent to a speech synthesizer, and he was able to “speak”.

In the US market, there are a few patents relating to head-mounted controllers. The patent entitled “Wearable head-mounted, glass-style computing devices with EOG acquisition and analysis for human-computer interfaces” describes a glasses-shaped device that uses electrooculography (EOG) sensors to detect eye movements (Figure 4). Traditionally, eye-tracking technologies rely on bulky cameras, but this 2018 patent makes eye-tracking more comfortable and affordable. The device consists of a glasses frame with electrodes on the temples. The reference electrode is located on the nose or behind the ears. The processor analyzes the signals and interprets the user's commands. This is a useful hands-free technology for people with special needs to interact with computers through eye movements in a discreet and comfortable way (Jin and Laszlo, 2018).

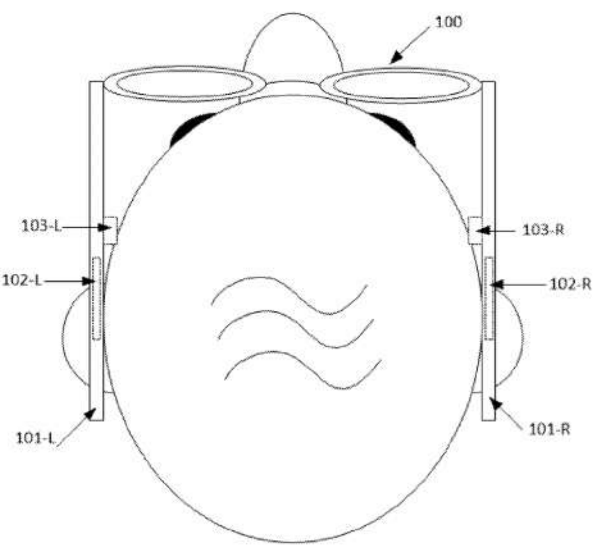


Figure 4: EOG Glasses (Jin and Laszlo, 2018)

Another relevant patent is the one invented by Uday Parshionikar's in 2024, which describes gesture-based systems and user interfaces that use multiple forms of body tracking, such as eye tracking, head tracking, hand tracking, facial expressions and others, such as body posture or voice commands (Figure 5). All this to interact with electronic devices such as AR/VR, wearables, human-machine interfaces for accessibility, gesture control systems in industrial or domestic environments, among others (Parshionikar, 2024).

Despite the various possibilities of using system navigation technology only with the use of the neck and head, this type of technological advance, in addition to being able to be employed in various types of technology, such as VR glasses, can also be used as a form of convenience for users without movement restrictions. For example, wearing VR glasses while holding a croissant in one hand and a coffee in the other. Or it could even be used by industry, if, for example, an employee on the production line has their hands full moving a heavy machine, and needs to move a second device. Using technology guided by head movements would give this freedom and convenience, even if the user has no physical limitations. To do this, in addition to the human physical limitations mentioned at the beginning of this chapter, there are also the limitations of the device to be used.

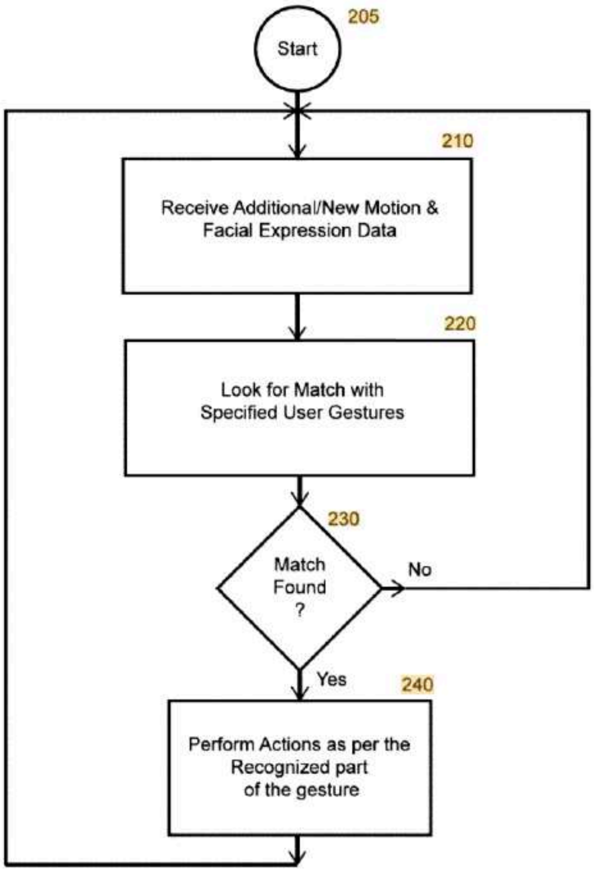


Figure 5: Gesture-based user interface system integrating eye, head, hand tracking and facial expression recognition (Parshionikar, 2024).

Considering the main object of this research, which is virtual reality glasses, 6 directions of freedom (6DoF) are considered, in other words, besides the three movements mentioned above in Figure 1, 3 other movements are generally already recognized by current glasses. However, some of these devices still need refinement in the detection of these gestures in various directions. Because, due to the low perception of the difference in types of direction, in the 6DoF context, movement A can be interpreted as movement B and vice versa.

2.1.3 6DoF control and torso movements

The 6 degrees of freedom (6DoF) is a term used mostly in robotics and mechanical engineering to refer to the 6 possible directions in which an object can freely move within a three-dimensional space (SANLAB, n.d.). They consist of up and down, forward and backward, left and right, roll, pitch and yaw.

Objects can move on the X, Y and Z axes, and inside each axis it can also change orientation (roll, pitch and yaw), which results in the 6 degrees of freedom. The 6DoF can be classified as translational and rotational. Translational refers to movement inside the 3 traditional axes that goes horizontally and vertically, up and down. Rotational refers to the rotation of an object to change its orientation (Coursera, 2025). Considering each axis, one can understand that translation in the X-axis means the movement along the horizontal axis, or left and right/side-to-side movement. Rotation in the X-axis means pitch, that is tilting forward or backward. In the Y-axis, translation means to move along the vertical axis, or forward-backward/front-to-back movement. Rotation in the Y-axis refers to yaw, or turning left or right. Translation in the Z-axis means movement along deepness, or up-down movement. Rotation in the Z-axis means roll, or tilting sideways.

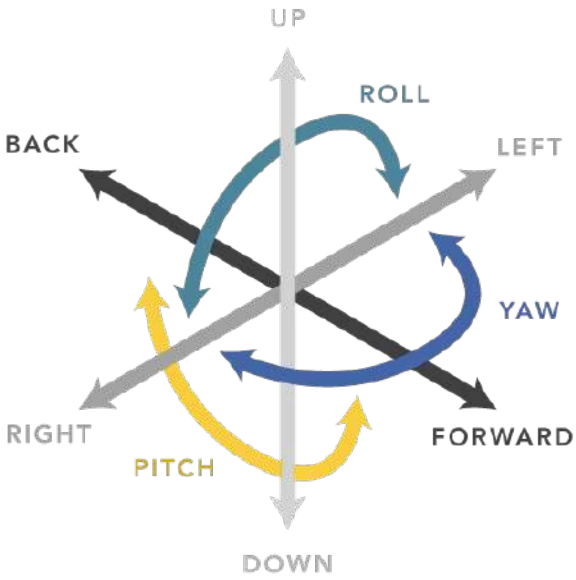


Figure 6: 6DoF (SANLAB, n.d.)

The 6DoF concept is multidisciplinary and can be used where control over spatial movement and orientation is important, such as in aviation, robotics, XR, vehicle safety design and more (Coursera,2025). Considering the definition aspects of the 6 degrees of freedom, the use of this concept in VR can create an even more immersive experience to the user. A headset with this technology, can offer similar sensations as being in the real world, for example while walking, crouching down and interacting with objects.

However, restricting the use of the 6DoF concept solely to VR headsets and considering body movement from the shoulders upward can significantly limit the capabilities of the device and constrain the overall user experience. This is particularly evident when compared to the full potential of VR hardware that includes both the headset and handheld controllers. Moreover, it is important to consider the natural biomechanics limitations of the human body - especially the head, which has restricted movement along certain axes. When combined with the physical constraints of the headset itself, these factors can pose challenges to implementing a head-only control system based entirely on 6DoF tracking.

2.2 Usability and efficiency in VR

Usability and performance in virtual reality (VR) systems represent two fundamental pillars for ensuring the acceptance and effectiveness of these emerging technologies. Usability, in this context, refers to the ease in which users can learn, operate, and interact with the virtual system, considering aspects such as comprehension, navigation, and satisfaction. As VR environments are highly immersive and interactive, usability depends on more sensory and cognitive factors than traditional interfaces. The immersion provided by head-mounted displays (HMDs), haptic gloves, and large projection screens transforms how the user perceives and reacts to content, requiring a human-centered approach to design and evaluation. In addition, problems such as cybersickness, visual discomfort, and adverse psychological effects need to be carefully monitored and mitigated if the system is to be considered usable.

On the other hand, performance evaluation in VR goes beyond hardware analysis. Although graphics processing and input and output devices are critical, performance in virtual environments also involves measuring delays, latency, tracking accuracy, and fluidity of responses to user movements. According to Ramaseri-Chandra, El Jamiy, and Reza (2019), the latency between the user's action and the visual response can directly impact the experience and cause discomfort. In addition, factors such as the user's gender, the type of device used, and even the complexity of the virtual scene influence perceived performance. Modern evaluations - mentioned in the Ramaseri-Chandra, El Jamiy, and Reza (2019) article - have included not only external sensors and high-speed cameras to measure delays but also brain-computer interface (BCI) technologies, such as EEG (electroencephalogram), to capture brain signals and provide data on the user's engagement and cognitive overload during the VR experience.

Despite the variety of existing techniques and approaches for evaluating usability and performance in VR, many studies focus on isolated aspects, such as latency or presence, without simultaneously considering the multiple layers that make up the VR user experience. The article's authors suggest that a hybrid model combining quantitative and qualitative methods - such as comparative tests, user interviews, physiological sensors, and task analysis - can offer a more complete view (Ramaseri-Chandra, El Jamiy, and Reza, 2019). In addition, it is necessary to broaden the spectrum of devices evaluated, promote tests with a greater diversity of users, and develop specific guidelines for each type of VR application, whether for games, training, medical simulations, or education. These actions can contribute significantly to advancing the quality and reliability of virtual reality systems.

2.2.1 Criteria and metrics for evaluating efficiency and usability in VR

Some metrics can be used to measure efficiency and usability in the virtual reality environment. For example, navigation efficiency. This can be measured by the time taken to complete tasks in the virtual environment and navigation accuracy, which measures the ability to arrive at the goal without errors along the way. The study by Eudave and Martínez (2025) investigated the effects of physical discomfort, called cybersickness, caused by exposure to immersive virtual environments. The tasks were carried out in an environment with different levels of immersion, including virtual reality (VR) with headsets and traditional desktop configurations.

Using a virtual maze task, the researchers compared two cybersickness assessment tools - the traditional Simulator Sickness Questionnaire (SSQ) and the more recent Cybersickness in Virtual Reality Questionnaire (CSQ-VR) - to measure symptoms such as nausea, disorientation and visual fatigue. The results showed that both questionnaires were reliable, especially in VR environments, where symptoms were more intense, but tended to decrease with repetition of the task, showing a habituation effect. Participants' performance did not vary between desktop and VR modes, but was slightly better in the second session of the day, indicating learning with practice.

The research also concluded that the SSQ performed better for detecting malaise on desktops, while the CSQ-VR proved more effective for VR environments, although both have limitations. The predictive analysis revealed that the display modality (VR vs Desktop) and the repetition of the task throughout the day were the main factors explaining the variations in Cybersickness levels, while individual characteristics and performance on the task had little influence.

The study by Eudave and Martínez (2025) highlights the importance of selecting suitable instruments for assessing malaise, depending on the modality used, and suggests that adaptation sessions prior to using VR can mitigate symptoms. These findings may be relevant to the design of experiments in neuroscience and cognitive psychology, helping to make VR experiences more effective and comfortable.

Another metric for evaluating efficiency and usability in virtual environments is the ease of use and the learning curve. The System Usability Scale (SUS) questionnaire is widely used to assess the perceived usability of interactive systems. As is the User Experience Questionnaire (UEQ). This is a standardized questionnaire that evaluates aspects such as attractiveness, perceptiveness, efficiency, reliability, stimulation, and novelty in the user experience of interactive products.

The third possible metric would be cognitive load. The measurement instrument would be the NASA Task Load Index (NASA-TLX), which assesses perceived workload in terms of mental, physical, and temporal demand, performance, effort, and frustration. Or the Paas Mental Effort Scale, which measures perceived mental effort while performing tasks. A critical analysis of cognitive load measurement methods by Friedl-Knirsch et al. (2024) highlighted the use of NASA-TLX and the Paas scale as approaches to assessing mental load in user interfaces, including virtual reality applications. The article presents a systematic review of the literature on user evaluations in Immersive Analytics, an interdisciplinary area that combines data visualization with immersive technologies such as virtual and augmented reality. Using the PRISMA[2] protocol, the authors analyzed 73 studies published between 2013 and 2022, identifying predominant methodologies and gaps in user evaluation in Immersive Analytics. The study highlights the need to develop a shared evaluation framework to standardize practices and facilitate comparisons between different approaches. Another evaluation point is physical effort. The NASA Task Load Index (NASA-TLX) can also help with this metrics.

The accessibility metric is also important for efficiency and usability in VR. The criteria should be compatibility with assistive devices, which assesses whether the VR system can be used in conjunction with assistive technologies such as screen readers or alternative input devices. In addition, customization of controls must be possible, which checks the system's ability to allow adjustments to the controls to meet the needs of users with different needs.

The article "Assessing Human Factors in Virtual Reality Environments for Industry 5.0: A Comprehensive Review of Factors, Metrics, Techniques, and Future Opportunities" by Escallada et al. (2025) presents a systematic literature review focusing on the evaluation of human factors in VR environments within the context of Industry 5.0. Analyzing 24 selected studies, the authors identify 29 human factors assessed through 240 distinct measurement methods. These factors are categorized

[2] Preferred Reporting Items for Systematic reviews and Meta-Analyses. It assists authors to completely report why their systematic review was done, what methods they used, and what they found (PRISMA, 2020).

into cognitive, physiological, and process-related domains, and further classified as pragmatic or hedonic based on their nature. Common evaluation tools include standardized questionnaires such as NASA-TLX, QUIS, and UEQ, as well as methods like eye-tracking and task performance metrics. The review highlights the lack of standardized assessment methods and emphasizes the need for a coherent framework to enhance the evaluation of human-centered VR experiences in industrial settings.

2.2.2 Assistive devices in XR

In the European Union, more than 80 million people live with some kind of medium or severe disability. According to the Bayerisches Staatsministerium für Familie, Arbeit und Soziales (n.d.), this represents around 15% of the EU's total population. Due to this demand, and considering that accessibility means providing everyone with the ability to perform tasks on equal terms with others, without difficulty and without external help. Since 2021, the EU has been adopting the “Strategy for the Rights of Persons with Disabilities 2021-2030”. This is precisely to ensure that, regardless of any special needs, everyone is included in society. Being protected from discrimination and violence and having equal access to the job market, health services, justice, education, culture, sport and leisure.

Considering the gadgets already mentioned in the previous chapter and the need for developing more accessible VR applications, one question appears. Would it be possible to connect some of these devices to a virtual reality headset? In standalone mode, connecting these devices would be more difficult, as many glasses only support input for controllers and hand tracking. However, if a PC is used and the VR headset transmits content from the PC, it is possible to connect customized devices.

In this scenario, the Moso Kinnsteuerung - for example - could be configured as an input device on the PC, and specific software could map its commands to actions within the virtual environment. A user with the Moso Kinnsteuerung connected to the PC could use the chin control to simulate joystick keys or axes, have these inputs mapped to actions within a VR environment made in Unity/Unreal, and control menus, movement, or interactions, using only the chin control.

In addition to the use of traditional controllers or hand tracking, people with disabilities can benefit from assistive technologies adapted to the context of virtual reality. Devices such as Envision Glasses, for example, allow visually impaired people to “see” information about the environment in real-time. With built-in cameras and artificial intelligence, these glasses describe scenes, read text aloud, and recognize faces and objects (Envision, 2024). Although Envision Glasses is not a VR headset on its own, similar technologies could be integrated into augmented reality (AR) or mixed reality (MR) experiences, especially when connected to a central system such as a PC.

Another accessibility case involves the use of voice commands and smart assistants. The Ray-Ban Meta Smart Glasses, for example, have built-in microphones and speakers, as well as access to the Meta AI assistant, which can respond to voice commands and perform simple tasks (Meta, 2024). Although these glasses do not have advanced VR or AR functionality (they are technically audio and camera devices with voice assistant integration), the concept of voice interaction can be replicated in VR environments, allowing users with reduced mobility or paralysis to interact without the need for physical devices.

Finally, there exists hardware that uses adaptive sensors, such as the Xbox Adaptive Controller, which connects to a variety of customized buttons and joysticks. In an environment with a PC and a connected VR headset (such as Meta Quest 3 in PCVR mode), it is possible to map these devices as inputs for games or experiences in Unity and Unreal Engine. With this configuration, users with limited mobility can use large buttons, pedals, or specific motion sensors to navigate and interact with the virtual world, significantly expanding the platform's accessibility (Microsoft, 2023).

All the devices presented in the previous paragraphs and chapters can serve as inspiration for functionalities to be included in virtual reality glasses. Or they can serve as devices that could be connected to a VR gadget like the Meta Quest 3, which is the hardware used in the tests of this research. Therefore, the table 1 below - Comparison of assistive devices - was created to identify possible accessibility technologies that could or could not be integrated with Meta Quest 3 to provide even more inclusion for people with special needs.

Table 1: Comparison of assistive devices

Device / Technology	XR Type	Category	Control Type	Compatible with Meta Quest 3	Standalone	Requires PC	Observations
Moso Kinnsteuerung	VR (PCVR)	Assistive input for controlling wheelchair	Joystick with chin	Maybe using PCVR	No	Yes	Mappable as a joystick via software on PC to control apps in Unity/ Unreal
Envision Glasses	AR / MR	Visual assistance	Vision + AI	No	Yes	No	Inspires AR/ MR solutions; does not connect to Quest 3 directly
Ray-Ban Meta Smart Glasses	None	Audio + Voice	Voice Assistant	No	Yes	No	Inspires voice interfaces in VR; no XR built-in
MyEcc (HomeBrace)	None	Assistive input for controlling wheelchair	Eye movement	No	No	Yes	Could control XR apps with mapping software if connected to PC
Munevo Drive	AR / MR	Assistive input for controlling wheelchair	Head movement (Android glasses)	No	Yes	No	Uses Android smartglass; concept applicable to controlling apps or robots
Tongue-Piercing Controller	VR (PCVR)	Assistive input for controlling wheelchair	Tongue position (magnetic)	Maybe using PCVR	No	Yes	Can send commands to PC; integrates with VR via mapping software

2.3 Current hardware platforms for VR navigation

Several hardware platforms currently dominate the VR navigation market, offering varying levels of immersion, tracking accuracy, and interaction features. Among the main systems, the Meta Quest series (especially Quest 2 and Quest 3) stands out for being independent, wireless, and widely adopted in consumer and research contexts, supporting hand tracking, and Inside-out tracking (without external sensors). Apple Vision Pro is standalone (with the possibility of Mac integration). It also has inside-out tracking with advanced sensors and eye tracking. Valve Index offers precise movement tracking with external base stations (Lighthouse system) and finger-tracking controllers, making it a benchmark for high-fidelity PC-VR experiences. PlayStation VR2 offers console-based VR navigation with improved tactile feedback and eye-tracking, accessible to a wider gaming audience. Finally, the HTC Vive Pro series is also widely used in industrial and academic applications, supporting robust tracking and modular upgrades. During the tests for this research, Meta Quest 3 will be used. Precisely because it is more accessible to the academic environment and because of its integration with PCs.

2.3.1 Meta Quest 3

Figure 7: Meta Quest 3 (personal file)

The Meta Quest 3 headset was released by Meta Platforms, Inc. in 2023. It features Dual RGB cameras with a resolution of 2064 × 2208 pixels per eye and a default refresh rate of 90Hz. It runs on the Qualcomm Snapdragon XR2 Gen 2 processor with an Adreno GPU (part of the same SoC) and comes with 8GB of RAM. There are two storage options available: 128GB or 512GB, but there's no microSD slot for expansion. For tracking, it uses six integrated cameras and supports depth detection. It also includes sensors like an accelerometer, gyroscope, magnetometer, and proximity sensor. The headset has built-in spatial audio with upgraded speakers, no 3.5mm jack, and supports both USB-C audio and Bluetooth headphones. Battery life is around 2.2 hours, and it charges via USB-C. Each controller uses one AA battery. It supports Wi-Fi 6E, Bluetooth 5.2, and USB-C for data and charging. The Meta Quest 3 works with both the Meta Quest Store and PC VR (through Quest Link or Air Link), and it comes with two Touch Plus controllers.

2.3.2 Touch plus controller

Meta Quest 3's Touch Plus controllers offer various features designed to provide an immersive and intuitive virtual reality experience. Each controller has an analog joystick for navigation and movement, triggers that allow you to select or interact with objects, action buttons (A and B on the right controller, X and Y on the left) used for confirmations or returns, and grip buttons on the sides that simulate grabbing actions. In addition, both controllers have system buttons, such as the Meta button on the right controller, which is responsible for accessing the main menu and refocusing the view. An important technical difference is that the Touch Plus controllers have capacitive sensors that detect the touch of the fingers on specific areas, such as the buttons and the upper part of the controller body, which allows for more natural and realistic interactions, such as pointing or simulating hand gestures without physically pressing the buttons (Meta, 2023a).

Although Meta Quest 3 doesn't have native eye tracking, it does offer support for hand tracking, allowing users to interact with the virtual environment without physical controllers, using only hand gestures. However, the functionalities of physical buttons, such as triggers and grips, are not automatically replaced by these gestures, requiring developers to create specific mappings to allow equivalent actions using their hands (Meta, 2023b). So far, there is no official support for fully customizing the buttons on Touch Plus controllers directly through the Meta Quest 3 system, but developers can use Meta's APIs to adapt the experience to different types of input, such as hand-tracking controls (AllVirtualReality, 2024).

Considering the technological possibilities of the Meta Quest 3 headset and the fact that it is possible to map some functions of the controls to other types of devices via PCVR. This research wants to explore initial forms of interaction with virtual reality applications using only head and neck movements. In this study, for example, the action of clicking the A and X buttons can be replaced by a gesture with the head. Besides that, certain joystick movements can be replicated by head rotations. It's important to note that, with the current sensors in Meta Quest 3, it's not possible to reproduce all the functions of the controls. To do so, it would be necessary to include additional devices, as discussed in the before in this research. Even so, this study can provide relevant insights into the efficiency and comfort of using virtual reality with interactions made exclusively with up-the-shoulder movements.

2.3.3 Meta Quest 3 comparison to other headsets

In order to understand some of the limitations and possibilities of the Meta Quest 3, it was necessary to compare this device with others available on the market, considering not only its features, but also the price range. Table 2 - Comparison of headsets - summarizes the technical specifications of major VR platforms, based on information from Meta (2023d), Valve (2023), HTC (2023), Sony (2023) and, Apple (2024).

Table 2: Comparison of headsets

Platform	Headset Type	Tracking	Main Imput	Usage Focus	PC Compatibility	Hand Tracking	Eye Tracking	Price Range (€)
Meta Quest 2/3	Standalone (PC opc.)	Inside-out	Controllers + hands	Games, social apps, training	Yes (Air Link)	Yes	No	300 - 550
Valve Index	Tethered (PC)	Outside-in	"Knuckles" Controllers	Games, simulations	Yes (SteamVR)	Non-native	No	~1000
HTC Vive Pro/Elite	Tethered / Mixed	Inside-out (Elite), Outside-in (Pro)	Controllers + hands	Corporate, simulation	Yes	Yes (Elite)	Yes (Elite)	600 - 1200
PlayStation VR2	Tethered (PS5)	Inside-out	PS Sense Controllers	Exclusive console games	No	Yes	Yes	~300
Apple Vision Pro	Standalone (com Mac)	Inside-out + LIDAR	Hands, eyes, voice	Productivity, Media	Parcial (MacOS)	Yes	Yes	~4000

2.3.4 Accessibility features in Meta Quest 3

Meta offers operational accessibility resources in Meta Quest. Some of these are: height adjustment, which improves comfort in perceiving the scale between the virtual world and the real world. Sound adjustment - ideal for people with unilateral deafness. Voice output, which is ideal to support people with visual impairments, or for users who have difficulty reading texts in a virtual environment. Color correction is also possible so the user can customize the display of the virtual environment. Contrast adjustment is another factor that improves accessibility for some individuals. Live subtitles, which are a written version of what others are saying - this feature depends on the language available. It is also possible to reassign the controller buttons, which allows the user to create different adapted button configurations. Another possible adjustment is in the font size in the main menu and in some applications that support this feature. Finally, Meta also offers the option of calibration of the thumb stick for a more comfortable interaction with the virtual environment depending on the user's needs (Meta, 2025).

3. Concept and Objectives

The goal of this study is to verify the efficiency, accuracy, and accessibility of virtual reality navigation based solely on head movements. Especially for users with disabilities who are unable to use controllers with their hands, torso, feet... Some virtual reality glasses have accessibility settings, but this study proposes a new approach to VR interaction accessibility design, called NavHead, which uses head gestures to enable a new possibility of hands-free control. Although assistive technologies for mobility already exist - such as head-based wheelchair control and eye-tracking systems - their integration in VR remains limited, especially in standalone headsets. The following sections summarize the gaps identified in the literature and form the research questions and hypotheses that guide the testing of this study.

3.1 Summary of identified research gaps

Despite the existence of accessibility features in some virtual glasses, such as the Meta Quest 3, mentioned earlier, and the Apple Vision Pro, which has more advanced accessibility features such as eye tracking, interface narration, customization of hand gestures, voice control, reduction of animations, among others. There is still a lack of integration between assistive technologies and VR, especially in standalone mode. Many devices (such as Munevo Drive, Moso Kinnsteuerung, MyEcc) were developed for wheelchair control or interaction with the physical environment, but are not integrated into VR experiences. There is also a lack of studies investigating how these technologies (or similar concepts) can be used for navigation in VR. In addition, there are currently little exploration of navigation based solely on head movement (6DoF). Most current virtual reality systems require a controller or hand tracking, which excludes users with motor limitations in their arms/hands.

There are few studies that analyze whether natural head movements are efficient enough for full navigation in VR. Currently, there is a lack of combined metrics that assess efficiency, accuracy, and comfort for head-only navigation. Research such as that by Ramaseri-Chandra et al. (2019) analyzes latency, fluidity, and technical precision, but does not directly address the accessibility of hands-free navigation. In addition, there are no consolidated guidelines for the use of alternative interactions in VR. Finally, accessibility in VR is still treated as a complement rather than a focus. Many devices such as the Meta Quest 3 have no official support for adaptive devices, other than through PCVR and manual mapping. There is a gap in the development of VR experiences where accessibility is the starting point, not just an additional feature.

3.2 Research questions and hypotheses

The growing integration of VR into everyday life highlights the importance of investigating interaction methods that are more inclusive, especially for people with motor limitations. In this context, the central question in this research is: “How do exclusive head movements (6DoF) impact efficiency, precision, and accessibility when navigating virtual environments for users with physical disabilities?”.

Based on this initial question, the following research sub-questions were formulated:

- (Q1) Does the exclusive use of the head as a method of navigation in virtual reality provide a comfortable and understandable experience for the user?
- (Q2) How accurate is the selection of elements in the virtual interface based solely on the positioning and rotation of the head?

- (Q3) Which selection method (e.g. 4-second pause or blow) is perceived as more natural, accessible, and effective by users?

Considering the previous questions, the hypotheses of this study are:

- (H1) Users find it comfortable and intuitive to use only their heads to perform basic tasks in a virtual reality environment.
- (H2) The system is able to accurately interpret head movements, allowing users to select elements with a low error rate.
- (H3) Among the selection methods tested, there will be a significant preference for one of them, indicating greater acceptance and perception of usability.

These hypotheses will be verified by analyzing the participants' performance in the proposed tasks and subjective evaluation using the post-test questionnaire, focusing on aspects such as comfort, frustration, cognitive effort, and perceived accessibility.

3.3 Differentiation: Why NavHead is novel

NavHead is an application developed for this research, that proposes a new paradigm for interaction in virtual reality environments by allowing users to perform tasks using only their head movements, without relying on physical controllers, hand recognition, or voice commands. This approach makes it particularly innovative due to its simplicity, accessibility, and focus on the inclusion of people with reduced or none mobility of the limbs below the shoulders or other motor restrictions.

Unlike traditional input methods, which require refined motor skills or specific devices, NavHead uses natural and intuitive head movements to make selections and activations in the virtual environment. Navigation is based on face orientation and activation by dwell (focus time) or by blowing (simulated via keyboard and a whistle). Reducing the need for complex interfaces and enabling a low-cost interaction model that is independent of additional hardware.

In addition, NavHead contributes to the field of inclusive design in virtual reality, a topic that is still little explored in empirical studies. The proposal offers a opportunity to investigate cognitive load, usability, and comfort in exclusively head-based interactions. It also proposes an ethical reflection on the creation of systems that are more respectful of the autonomy and dignity of users with different needs. NavHead is innovative for reinventing VR interaction through a minimal and accessible system that eliminates technological and physical barriers, promoting a more democratic and human-centered experience.

4. NavHead Application

The application developed with Blender, C# and Unity, for Mets Quest 3, consists of a floating virtual living room environment, in a world inspired by Avatar's Pandora, with images created by artificial intelligence. In this living room, there is a functional cube that acts as an interaction menu (Figure 8).

Figure 8: NavHead Living Room (personal file)

The user rotates the cube using only head movements (without using hands or controllers). The movements consist of neck flexion (Pitch), neck rotation (Yaw), and lateral bending (Roll), as exemplified in Figure 9. When the user is introduced to the virtual environment, he is faced only with the room, without the cube. After the researcher clicks the "C" key, the cube appears.

The selection of one of the cube faces is done in two ways: By remaining with the desired face in front for 4 seconds. In this way, the position of the main camera is aligned with the face of the cube in front of the user, and this creates the selection, since the Meta Quest 3, the headset used in the research, does not have eye tracking. Another type of selection is by clicking the “S” key on the keyboard, activated by the researcher during a strong blow from the participant (simulating an alternative trigger accessible to people with severely reduced mobility). Selection types can be toggled in the system by pressing the "L" key.

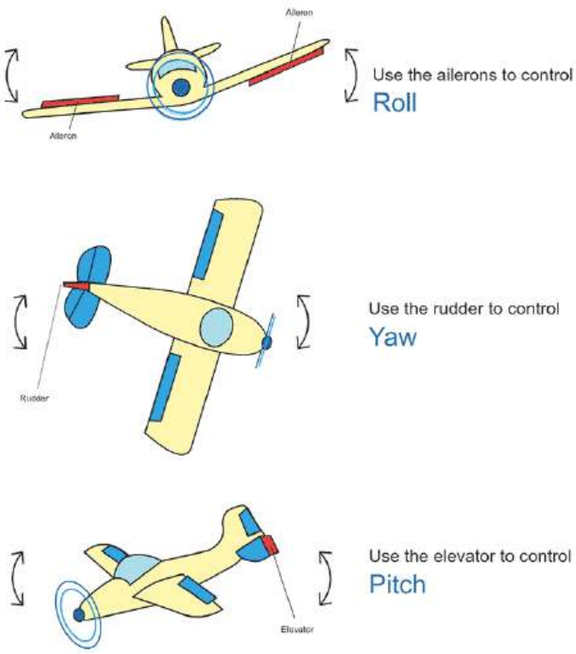
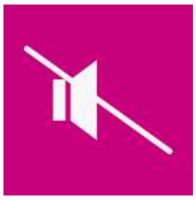


Figure 9: Roll, Yaw, and Pitch (Smithsonian National Air and Space Museum, n.d.)

The action of pressing the keyboard keys to navigate between functions, activate the cube, or select by blowing, is an analogical way for the researcher to focus on the movement of the cube and selection of menu items (cube) solely with the head while maintaining the fluidity of the test.

The actions available in the environment, considering a menu in the shape of a cube with six faces, are: Turning a lamp in the room on and off, turning the ambient sound on/off, turning the television on/off, changing the external environment to night mode (as the room is floating, the external environment becomes a galaxy), activation of warning mode, and activating or deactivating the instructions banner (Table 3).

Table 3: NavHead function map

Function	On	Off
Lamp		
Ambient sound		
TV		
Night Modus		
Warning modus		
Instructions		

To indicate to the user whether the active selection mode is by blowing or by aligning the face with the cube face, in the bottom right-hand corner of the user view there is an image representing each mode. In addition, as mentioned previously, there is an instruction option in the menu, so when activated, the instructions banner is also positioned on the right-hand side of the user's view (Figure 10).

Figure 10: Instructions and selection mode (personal file)

4.1 Functionality and architecture

The application consists of three scripts: GameController, CubeHeadController and CubeFaceSelector. The GameController controls the visibility of the cube, it saves the initial position, rotation and scale of the cube. The script also gets the CubeHeadController component of the cube itself and disables the cube (makes it invisible when starting the game). It allows the user to show or hide the cube by pressing the C key, If the cube is activated It calls ResetToInitialState(...), to make the cube returns to its initial state.

Figure 11: Cube (personal file)

The CubeHeadController.cs controls the rotation and scaling of the 3D cube in Unity, based on the user's head movements while wearing the Meta Quest 3 headset. The script uses the Main Camera reference (headTransform) as the starting position and as a reference to identify rotation to the sides (Yaw), upward and downward tilt (Pitch), and lateral tilt (Roll).

Another important logic made with this class is the “groundReference”, which is the reference of the ground in the virtual world to know what is up and what is down in the global orientation. The reference used as ground in the code is the game object “Floor”, therefore the coordinates of the game object “Floor” represents the ground base for the “groundReference”. The “rotationSpeed” is a value that indicates the speed of rotation when turning the head, so that it is comfortable for the user to also see the menu symbols on each face of the 3D object while turning the cube. To identify the minimum angle in degrees for rotation, the “rotationThreshold” value is used. The same works for the zoom (Roll) with the variable “zoomThreshold”, which identifies the minimum angle to identify the movement. The speed of the Roll is measured by the value in “zoomSpeed”. To improve usability, some private variables in this script work to capture the value of the initial position, such as “neutralPosition”.

In unity, during the first second (calibrationDelay), the player's camera is calibrated to save the rotation and neutral position (neutralEuler, neutralPosition). This is done every frame via Update(). This “zero position” serves as the basis for detecting how much the head has moved afterward. After calibration, the main function for interpreting head movements is called the HandleGestures() method. The code checks which of the 3 axes (Yaw, Pitch, or Roll) has the greatest deviation from the neutral position. Based on this, it applies the corresponding transformation to the object:

- Dominant Yaw → Horizontal rotation.
- Dominant pitch → Vertical rotation.
- Dominant roll → Zoom (scale change).

The third class is CubeFaceSelector.cs. This script allows the user to interact with different faces of a 3D cube based on the direction of the camera (head tracking). When the user keeps their head (and therefore the camera) pointed at one of the faces of the cube for 4 seconds “headTransform.forward”, the functionality corresponding to that face is activated or deactivated (Alignment of the user’s face with the cube). For testing purposes it is also possible to trigger the selection with a keyboard letter “S”. This is a way to simulate the user's blow as a selection mode during testing. In this script the logic of switching between selection types also happens. By pressing the “L” key it is possible to switch between selection mode by blowing or by face alignment.

The script executes the action in Unity associated with the selected face based on its tag. Each change also modifies the material of the face to visually reflect the new state. Interaction options include:

- Turn light on/off
- Turn on/pause background music
- Switch between day/night mode

- Turn a "TV" on/off
- Enable red ambient light
- Show or hide instructions

The image 12 illustrates the interaction logic between the user and the cube interface. It begins with the cube being activated, followed by a decision point where the system checks whether the user is in Align Mode (“gaze”-based interaction) or keyboard mode. In Align Mode, the user selects a cube face by looking at it for 4 seconds, while in keyboard mode, selection is triggered by pressing the “S” key. If the user selects a face by alignment, it takes 8 seconds for the same function to unlock again. Once a face is selected, the system executes the corresponding action.

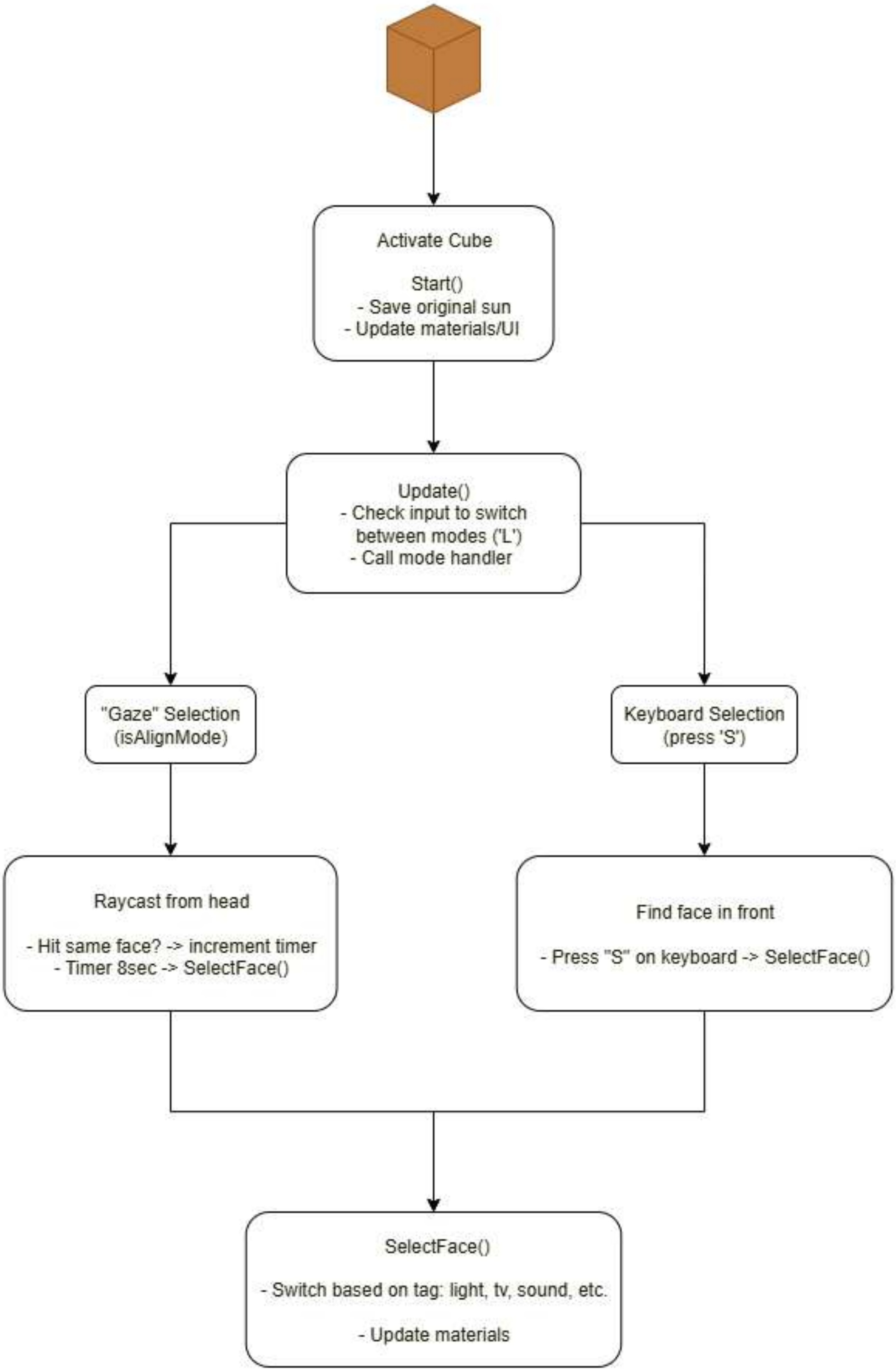


Figure 12: NavHead flowchart

4.2 Identified problems and limitations

During the research, one main headset limitation was found. The device used for the development of the application - Meta Quest 3 - does not have eye tracking. This was one main problem to solve, as one of the ways to create the select function, was through gaze tracking. The user should be looking/pointing to a cube face for 4 seconds and the face would be selected. The way to solve this problem was using the position of the main camera on Unity. The camera is always pointed to the cube, which is rotating accordingly with the head command. If the user stops the rotation of the face to be selected, the user can hold the desired cube face in front of his/her face and, if the main camera is pointed to the face for at least 4 seconds, the face will be selected. Considering that the user's face is the main camera perspective, the sensation that the user has is that, if he looks at a face in front of him/her and holds it for 4 seconds, it will be selected.

Another limitation was related to the 6DoF. Because of the head anatomy, it is not possible to move the head in some axes. Therefore, it is possible to have a clear movement in 3 directions, and the other 3 Up and Down, Forward and Backward, and Left and Right, are almost not possible or definitely not possible to be made if the user has no movement from the shoulders down. For example, the up and down movement is anatomically not possible to be made just by the head and the neck. Maybe the user could stand up and sit to create the up and down effect, but in the case of this study, the user has no movement on the lower 2/3 parts of the body, which makes this movement impossible to use as any type of commando. Another problem would be, that even if the up and down movement could be possible, the overlapping between commands could easily occur. Up and down could also read as pitch. Thus, the headset should have a really fine sensor to detect any small movement differences and alterations. The same problem occurs for example with yaw and roll, as sometimes the Meta Quest 3 overlaps these two commands.

5. Methodology

This chapter explains the methods for creating the test, and give an overview of the project. Three aspects are important to the core of this thesis: Navigation efficiency, Accuracy, and Accessibility in VR. Thus, in addition to theoretical research focusing on showing practical examples of assistive devices handled only with the head. An application called NavHead was created to support the test that aims to evaluate the three pillars mentioned. The importance of this study lies in researching alternative modes of VR navigation. This can enable more inclusion for people with disabilities, as well as for industrial tasks, product sampling fairs through virtual reality… In general, in environments where the use of hands as controllers may be compromised.

5.1 Study design and experimental procedure

The research is experimental, with a quantitative approach and qualitative support. It is exploratory and descriptive. The study aims to investigate the efficiency, accuracy, and accessibility of navigation in virtual reality environments using exclusively head movements (6DoF), especially for people with severe physical disabilities. The methodological basis involves the development and practical application of an interactive VR prototype, complemented by data analysis of participants' performance in specific tasks and structured questionnaires with space for open comments.

5.2 Participants (inclusion/exclusion criteria)

The target audience used as participants in the research is an adult with a severe physical disability, who only has control of their head and neck. If it is not possible to find participants with this profile, people without disabilities will participate by simulating restricted movement from the shoulders down. The estimated number of participants ranges from 5 to 10 people, the inclusion criteria are people aged 18 or over, with full control of head and neck movements. The exclusion criteria are: a history of severe VR sickness, photosensitive epilepsy, or uncorrected vision problems.

5.3 Softwares and hardwares

The NavHead application was developed using Unity 3D to create the virtual environment, with task logic implemented in C# using Rider, a cross-platform IDE for .NET and game development by JetBrains. Additionally, Blender was used to create several 3D assets, including the sofa, windows, table, and television. As for hardware, a Meta Quest 3 headset and a Windows computer were used. Furthermore, the research setup required a chair or armchair, as users without locomotion or mobility impairments below the shoulders were asked to simulate such conditions.

5.4 Experimental conditions and control measures

To ensure consistency between the tests, all participants will take the test in the same virtual environment, with the same initial lighting and sound conditions. The device will be the same for everyone (Meta Quest 3). All participants will receive initial standardized instructions and will be able to access the instructions banner at any time within the application itself. Participants without motor disabilities will be instructed and controlled not to use not allowed limbs, such as the arms and back. Finally, all participants will receive tasks in random order and, in different combinations, to mitigate the risk of data corruption.

5.5 Task description

Participants will be required to perform five tasks in the virtual environment, such as turning on a light and turning off ambient sound, among other tasks. The assignments can be performed without a time limit, but the execution period will be timed for later analysis. The tasks will be chosen randomly, but two of these tasks must be performed by blowing selection, and the other two by pausing the face in front of the desired face of the cube. The first and last tasks will be the same, turn on/off the instructions, but with the selection method alternated. In the first and last tasks, the cube is positioned in the same initial way, in order to obtain a zero point for comparison.

The user have to be seated to be able to perform the tasks, and if the participant has no body limitations, the user will not be allowed to move from the shoulders down. At the beginning of the test, the user answers a demographic questionnaire. At the end of the tasks, participants will answer a questionnaire with 12 questions on a Likert scale from 1 (I completely disagree) to 5 (I completely agree), addressing criteria such as comfort, efficiency, accuracy, and accessibility. The Likert scale of 1 to 5 was chosen because it allows for a neutral point (number 3), it is a simple scale that is easy for the user to understand and it is a scale commonly used in UX research, marketing, education, as it facilitates data analysis. The questions were based on the types of questionnaires mentioned in subchapter 2.2.1 "Criteria and metrics for evaluating efficiency and usability in VR". At the end, there will also be an open field for spontaneous qualitative comments.

5.6 Collected variables

The variables measured during the experiment include the total time taken to perform each task - efficiency. The accuracy of the cube face selection. The number of errors, such as accidentally changing the face or waiting incorrectly. Number of attempts until correct execution. In addition, in the post-task questionnaire, it will be important to understand the perceived level of comfort. It will also be important to know if the user experienced any frustration when performing the tasks, and also if they had difficulty using only their head as a controller. This aspect also falls within the scope of the application's efficiency. The program's accuracy will also be measured by finding out, for example, whether the participant had any difficulty stopping the cube in the desired position. Accessibility will be checked by finding out from the participants whether the interaction can be useful for people with motor limitations. And whether the user felt respected when using this alternative interface (in the case of a participant with a motor disability). At the end, the participant will be free to make suggestions and report difficulties that were not addressed in the questionnaire.

5.7 Pre-Tests

The goal of the pre-tests is to test the NavHead application with a small number of people to identify usability flaws, calibrate waiting times, and validate interactions with the cube before the final test. The estimated number of participants in the pre-test is 3 to 5 adults without disabilities, but simulating movement restrictions below the neck.

5.8 Ethical aspects

The project is conducted in accordance with the guidelines of the Ethik-Selbstreflexionsbogen (Ethics self-reflection sheet - translated independently) of the University of Media (Hochschule der Medien - HDM). Therefore, it is ensured that participation will be voluntary and by means of an informed consent form. There are no significant physical or psychological risks, except the slight potential for motion sickness. Data will be collected anonymously and used exclusively for academic purposes. Participants will be allowed to withdraw their consent and leave the study at any time without any prejudice.

6. Demo Application and Pre-Study

The questionnaire was made available in English and German, and was divided into demographic data, a researcher's notes page, a Likert scale questionnaire with 12 questions that covered the types of questionnaires such as CSQ-VR (Cybersickness in Virtual Reality Questionnaire), NASA-TLX (NASA Task Load Index), SSQ (Simulator Sickness Questionnaire), SUS (System Usability Scale) and UEQ (User Experience Questionnaire). After the quantitative questions, there were also qualitative questions, which aimed to get more complete feedback from the participants.

Considering that the pre-tests served as a basis for adjusting the final version of the test. Each user was given 4 tasks, such as turning the light on or off, turning the sound on or off, turning on night mode, and opening the instructions page. Two tasks had to be solved with the selection made on the basis of blowing, and then two tasks with the selection made on the basis of aligning the face with the face of the cube for 4 seconds. This stage of the selection format was done randomly, i.e. one user started with the task of selecting by blowing, while the other started the task by selecting with the alignment of the face.

6.1 Pre-Tests results

6.1.1 Demographic data

The pre-tests were carried out with 3 adults, aged between 20 and 40, who do not have any physical disabilities and who have little or no experience with virtual reality glasses. There were two adult males and one adult female. Each participant's occupation was a software developer, educator, and student. Graphs related to demographic data can be found in the attachments at the end of this study (Figures 40 to 43).

6.1.2 Quantitative evaluation (Likert scale)

Participants demonstrated that using the head as a controller was comfortable, but accuracy had mostly a neutral opinion, with 2 of the 3 participants indicating neutrality in the accurate use of only the head as navigation.

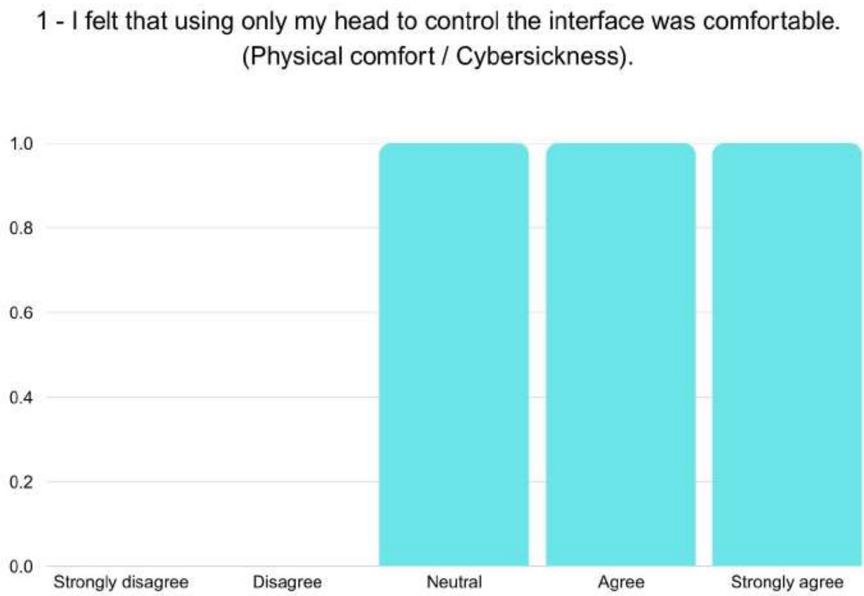


Figure 13: Pre-Test - Question 1

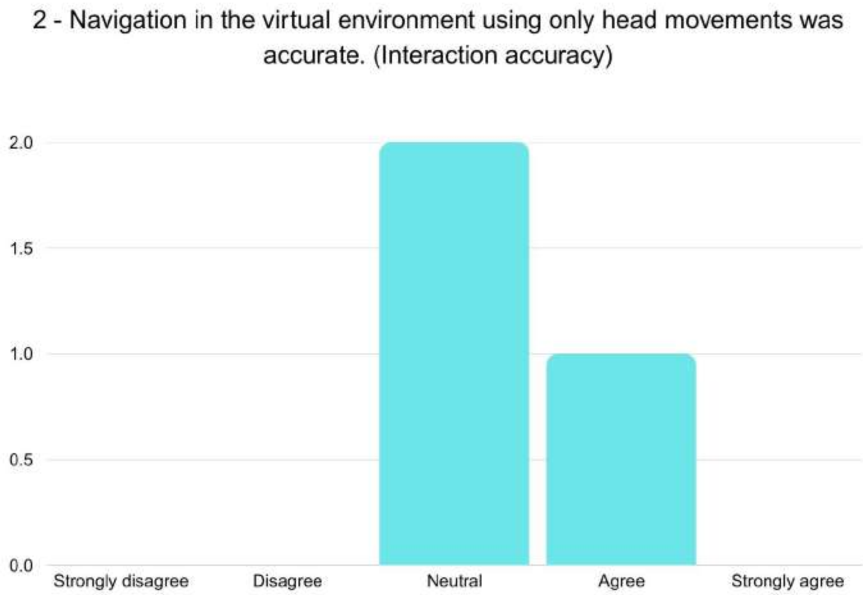


Figure 14: Pre-Test - Question 2

2 of the 3 participants indicated that they could quickly understand how the controller works using just their head. And 1 of the participants had difficulty stopping the cube on the intended face.

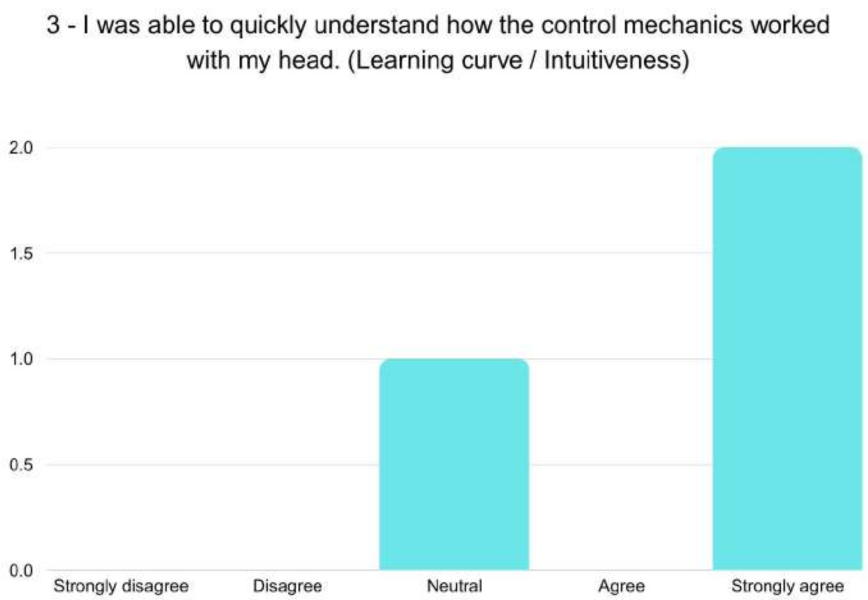


Figure 15: Pre-Test - Question 3

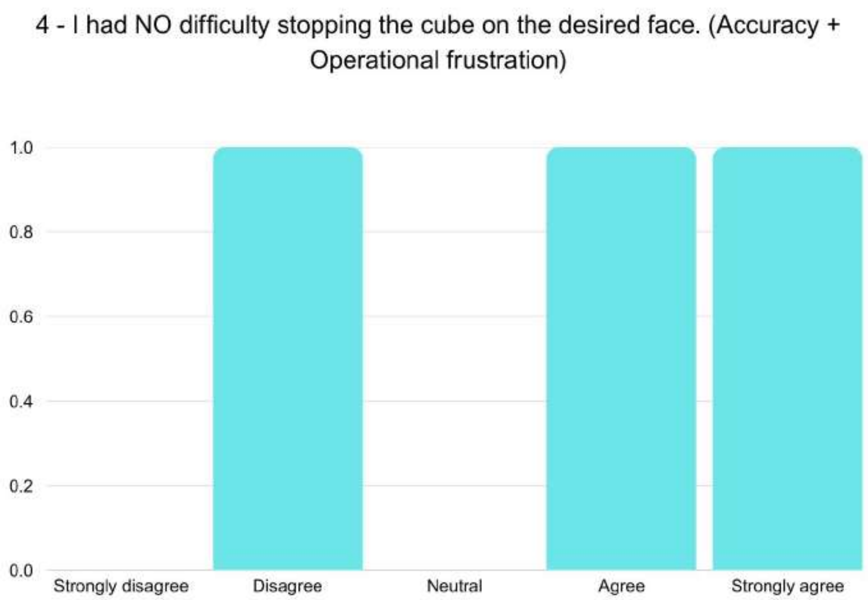


Figure 16: Pre-Test - Question 4

The blow selecting method was preferred by participants, with opinions ranging from neutral to strongly agree. The option of selecting by aligning the user's face with the face of the cube was less appreciated, with opinions ranging from disagree to neutral.

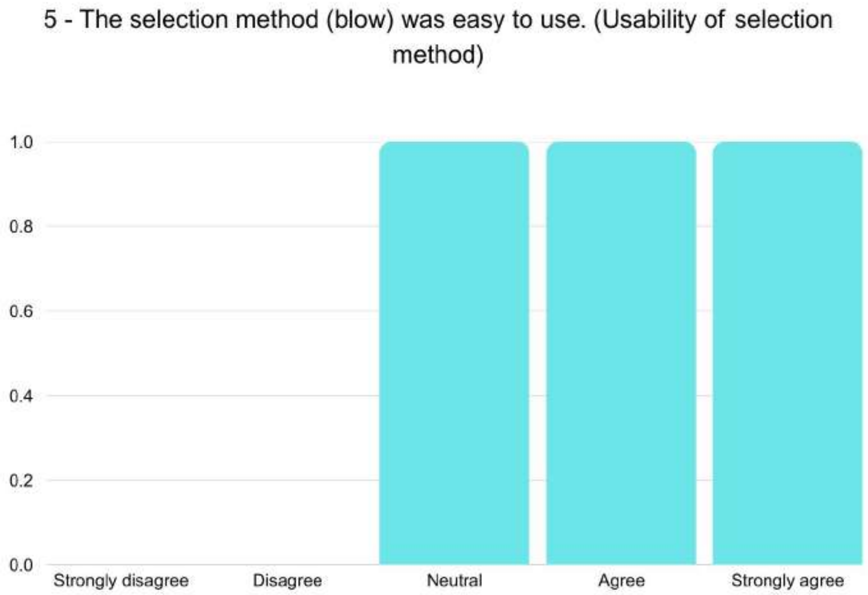


Figure 17: Pre-Test - Question 5

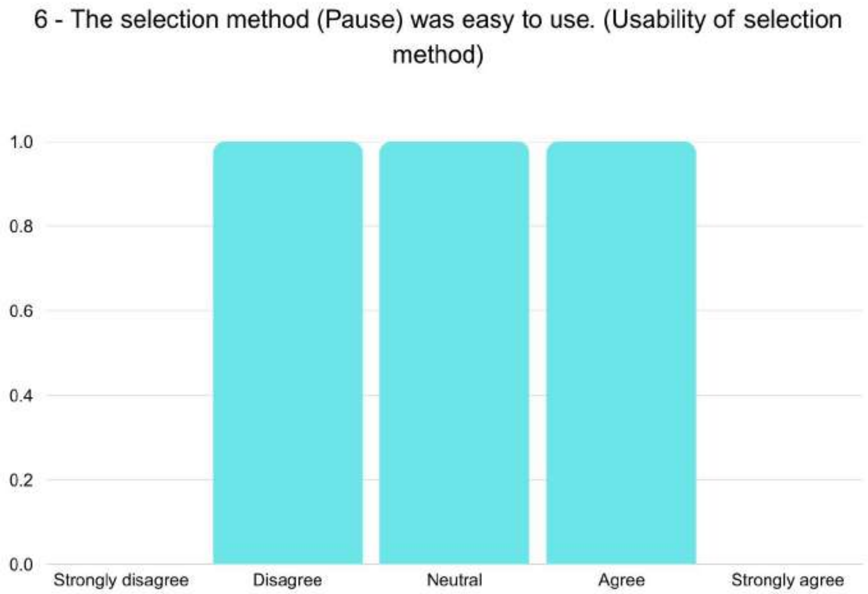


Figure 18: Pre-Test - Question 6

Most participants indicated neutrality regarding the mental load of the tasks. And most indicated no discomfort with cybersickness.

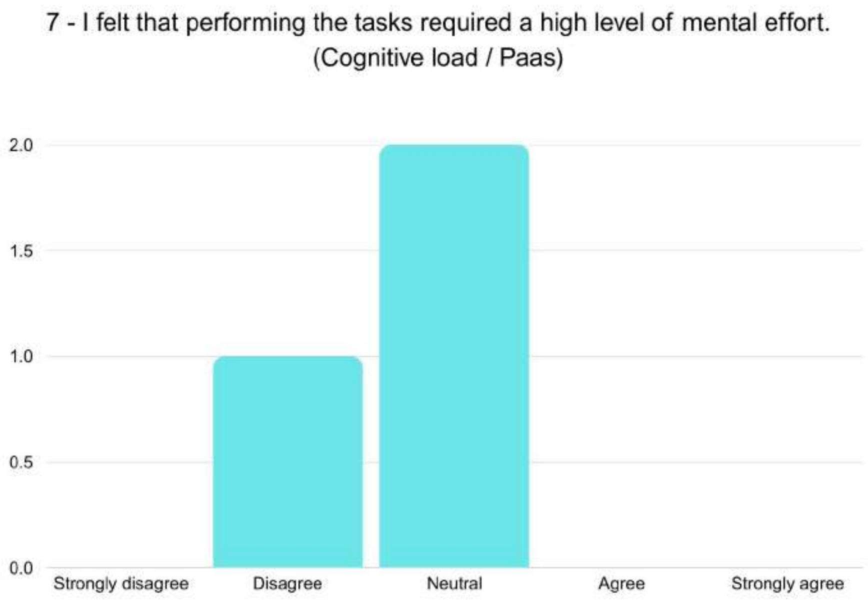


Figure 19: Pre-Test - Question 7

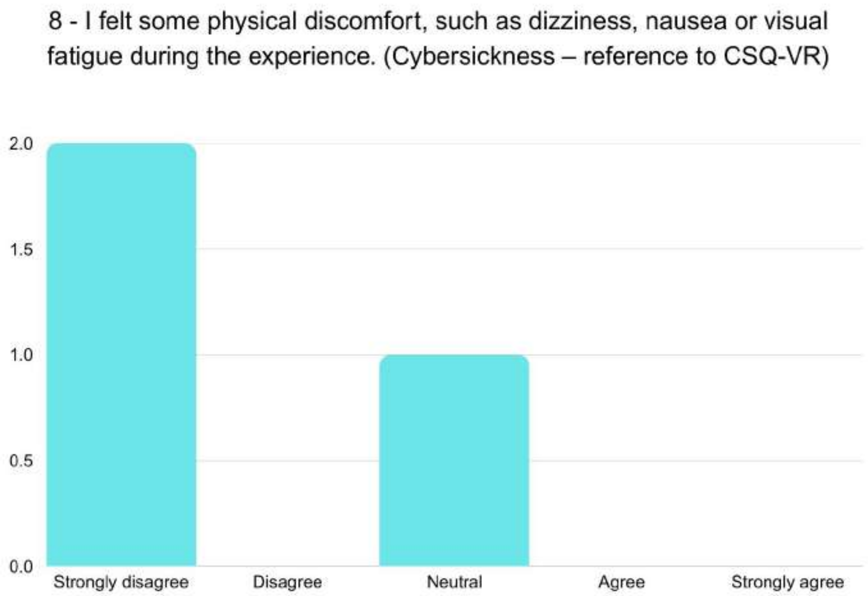


Figure 20: Pre-Test - Question 8

Participants did not report frustration with using only their heads as a controller. And they all believe that this application is an important tool for people with disabilities.

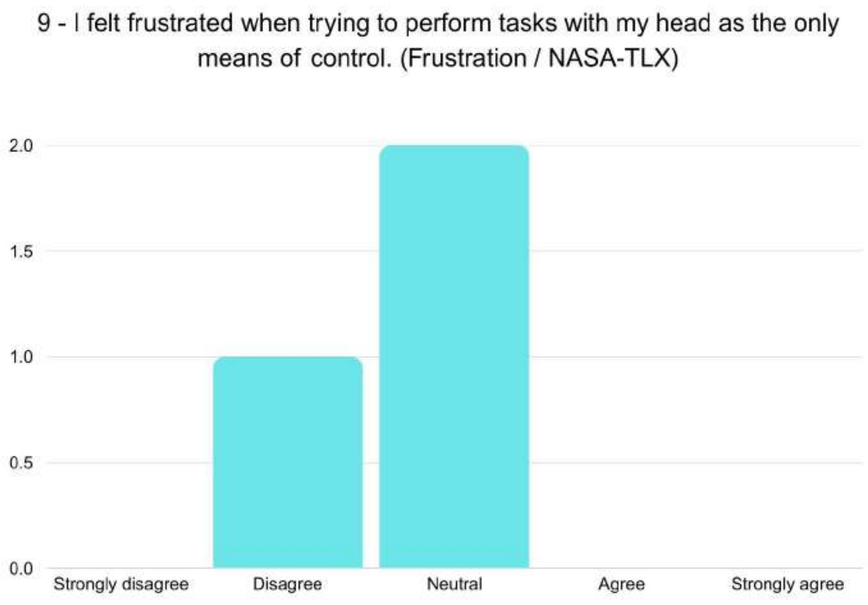


Figure 21: Pre-Test - Question 9

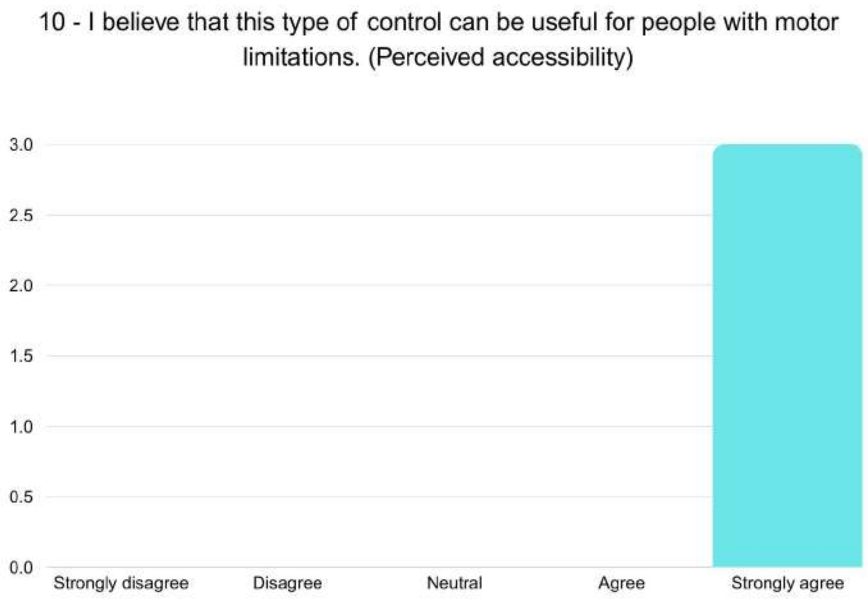


Figure 22: Pre-Test - Question 10

Most participants indicated that the interface did not respect the time to perform tasks correctly. However, everyone imagined themselves using this type of controller only with their head.

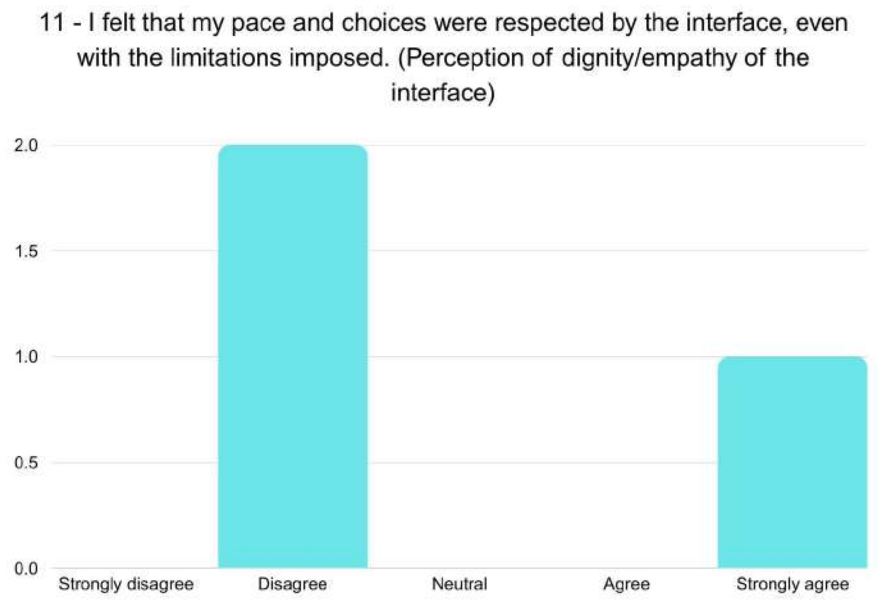


Figure 23: Pre-Test - Question 11

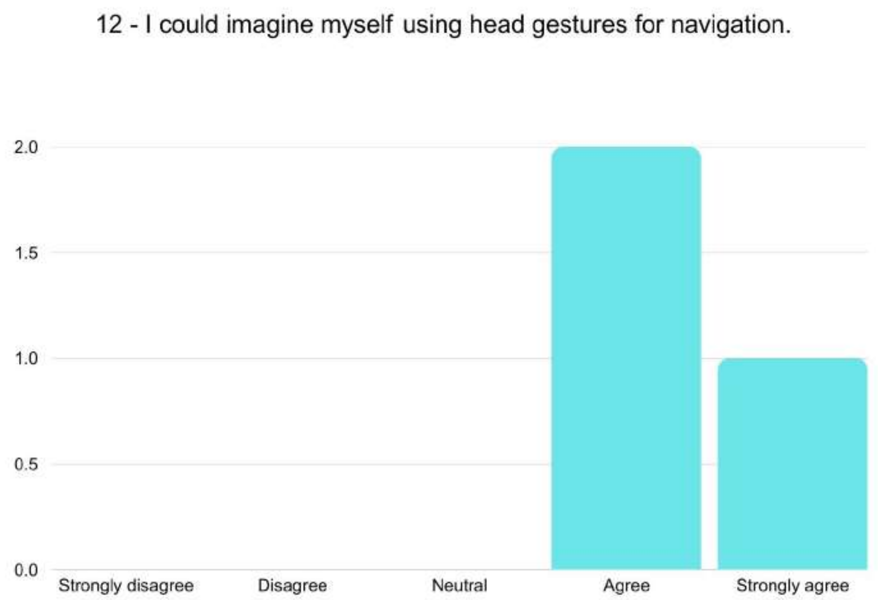


Figure 24: Pre-Test - Question 12

6.2 First time observation and Problems found

Based on observation and the qualitative answers from the survey, it was possible to get more detailed feedback on the improvements needed in NavHead. The three qualitative questions consisted of:

1. Describe in your own words what your experience was like using only head movements to interact with the virtual environment.

2. Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?

3. Do you have any suggestions for improving this type of head-only interaction?

During the test, it was noticed that, because the users had little or no experience with VR, at the start of the application they got excited looking at the whole environment and trying to "touch" the virtual environment, forgetting that this was a test in which the person was only supposed to move their neck and head. This action of moving their head uncontrollably to all sides caused the cube, which acts as a menu, to move randomly. This highlighted the need for a start button, to give the participant time to familiarize themselves with the environment.

Another observation concerned the test time. After familiarizing themselves with the virtual reality environment and actually starting the test with the tasks, all the participants finished the test within 4 minutes, not counting the time taken to fill in the demographic data and the questionnaire. The participants noticed that after the first contact with how to handle the cube with their heads, the tasks became easier and more intuitive. The total test time was around 15 minutes. This seemed a comfortable time for all users.

One of the participants didn't feel frustrated at any point during the tasks, but the other two did. One participant felt frustrated when trying to rotate the cube by moving the pitch, and another felt frustrated when selecting the face of the cube by aligning the face. In addition, during the test application, NavHead-VR worked well, with only one bug with a user at the time of familiarization with the environment. However, none of the participants complained of feeling nauseous or any kind of discomfort. But, before putting the application to work, there were several bugs related to Meta Quest 3. There were some updates to the headset software, which made it difficult to connect the headset to the computer, even using a USB-C cable to have a more stable connection than just via Air Link. This problem persists to this day. After a few updates to the computer app, this problem has improved, but it still takes a while, and sometimes it's necessary to restart the PC to achieve smooth navigation with Meta Quest 3 in PCVR mode.

Another problem was the speed at which the cube rotated. Two of the three participants complained that the speed was too slow. Finally, it was noticed that even when the selection mode was blown, sometimes the selection by pausing the face happened. This can be solved by creating a function that turns the selection function mode on or off. In this case, it is necessary to add a responsiveness icon referring to the selection mode, when a predetermined key is selected, the selection function by means of the blow is activated and the selection by the alignment of the face is deactivated and vice versa.

7. Main Application and Study Results

The final application was adjusted based on the results of the pre-test. The changes were: Adding a start mode for the user. When the user starts in the virtual room, they don't see the cube, so they can experience the environment before the test, preventing the cube from rotating randomly while the user just tries to see the room, and not perform tasks. By pressing the letter “C” on the keyboard, the cube is activated, and the study begins. Another adjustment based on the pre-tests was concerned to the selection method. In the final version, there is a way to switch between selection methods by pressing the letter “L” on keyboard, preventing one type of selection from overriding another. All the actions of pressing a keyboard key were done by the researcher and not by the users, as the aim of the research was not to use any type of control other than the head and neck.

There were a total of 10 participants, 5 without disabilities and 5 with some disability, 3 of whom had severe paraplegia. All of them have had disabilities since birth, mainly acquired at the time of delivery. Due to the participants' respective disabilities from birth, especially in the more severe cases, I was told that their mental development did not keep pace with the growth of their bodies. Due to this set of factors, it was not possible for some of them to carry out all the intended tasks. Therefore, the data will be divided between people with disabilities and people without disabilities, and at the end, a comparison of this information will be made. The tests took place between July 4 and 8, 2025. The tests with all people with disabilities took place at the Körperbehinderten-Verein Stuttgart e.V. (KFV) on July 8th. All participants met the inclusion criteria mentioned in Chapter 5. The questionnaires with the collected data are in the attachment of this research.

7.1 Descriptive analysis of the experimental context

All the participants seemed excited about the tests. In environments with people without disabilities, it was noticed that the virtual reality glasses generated curiosity and excitement. In the environment with people with disabilities, curiosity and excitement were also generated, so they prepared a room for those who wanted to see, to watch the interaction of people with glasses. This was part of the day's program at the institution. All the participants were volunteers. There was also an exchange of observations, and it was reported that they value this research because there is no point in creating accessible systems without testing them with people with disabilities. In addition, due to the individual limitations of each person, it was noted that everyone was tolerant of the different opinions of each participant, as they understand that a system can be very good for one individual, but not so suitable for others.

People without disabilities followed the test as indicated in the methodology. They were given 5 tasks, the first and last were the same tasks to indicate a start point and an end point, and the 4 tasks were divided into two groups: selection by aligning the face and selection by blowing. This was done in alternating ways to avoid data bias.

People with disabilities didn't follow the test schedule, because due to the different types and levels of disability, some of the movements weren't possible. The yaw movement (rotation of the cube to the right and left) was the most accessible for disabled participants, including those with severe disabilities. However, Roll (zooming the cube) and pitch (rotating the cube vertically, up and down) were not accessible to all participants. In addition, two participants with severe paralysis refused to use the blowing method as a selection method.

In empirical observation, the levels of special needs seemed to be quite varied. While 2 of the 5 disabled people could walk, with some level of difficulty. The other 3 needed a special chair or a type of chair with an inclination that resembled a bed. The position of these people's heads also varied, as in some cases the head was not aligned with the neck or body. Head movements also varied, for example, the person who needed to use a chair/bed could only move a little sideways (Yaw - right/left). Of the two people who could walk, one had difficulty with his hands.

7.2 Demographic data

10 adults voluntarily participated in the final test. Among them, 3 men and 7 women. 4 people are between 29 and 39 years old, 2 people between 40 and 50, 2 people between 51 and 61, 1 between 18 and 28, and 1 person between 62 and 72 years old. 5 out of the 10 participants have little experience with VR, and the remaining have no experience with VR. 50% of the participants have some form of disability. 40% of the participants are unemployed, a data that comes mostly from those with severe disabilities. The other participants are employed as a social worker, designer, engineer, accountant, consultant, and office worker. The charts with demographic data are in the attachments of this research (Figures 44 to 47).

The disabilities mentioned were spastic paralysis, what, according to the Austrian health portal Gesundheit.gv.at, is when one or more muscles are permanently contracted, and happens due to damage between the brain and the spinal cord. Another disability was visual impairment, where one of the participants reported not being able to see well. And one participant reported having chronic polyarthritis with restricted mobility, which is an autoimmune disease that causes inflammation in the body and affects the joints (Sanubi.de, n.d.).

7.3 Quantitative evaluation (Likert scale)

The graphs are divided between data from individuals without disabilities in orange and data from individuals with disabilities in red. The questionnaire could be completed by all participants; however, as mentioned, the data, despite being comparable, can only serve as a trend. Besides the small sample size, the testing schema for individuals with disabilities was adjusted to each individual's needs, while the test for individuals without disabilities followed the schedule indicated in subchapter 5.5 Task description and 7.1 Descriptive analysis of the experimental context.

Overall, participants found using their head as a way to control the application comfortable, with the "I completely agree" option representing 3 of the 5 participants with disabilities, and 2 participants without disabilities. However, this number is tied to neutrality in the sense of comfort for those without special needs (Figure 25). Regarding accuracy, due to the different levels of special needs, this data was spread among people with disabilities, varying mostly between the "I strongly disagree" and "Neutral" options. Meanwhile, people without disabilities marked only positive options, reporting that the application's accuracy was good or excellent (Figure 26).

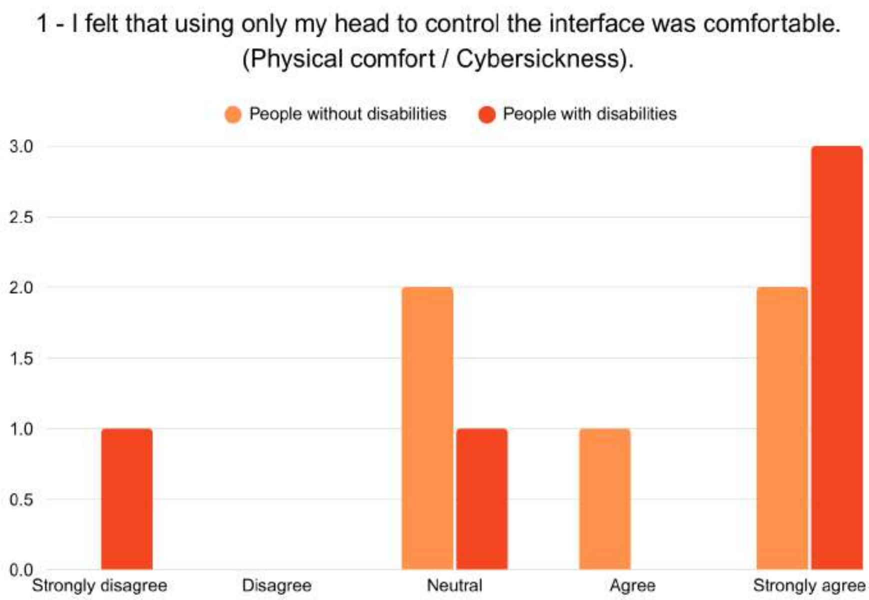


Figure 25: Main-Test - Question 1

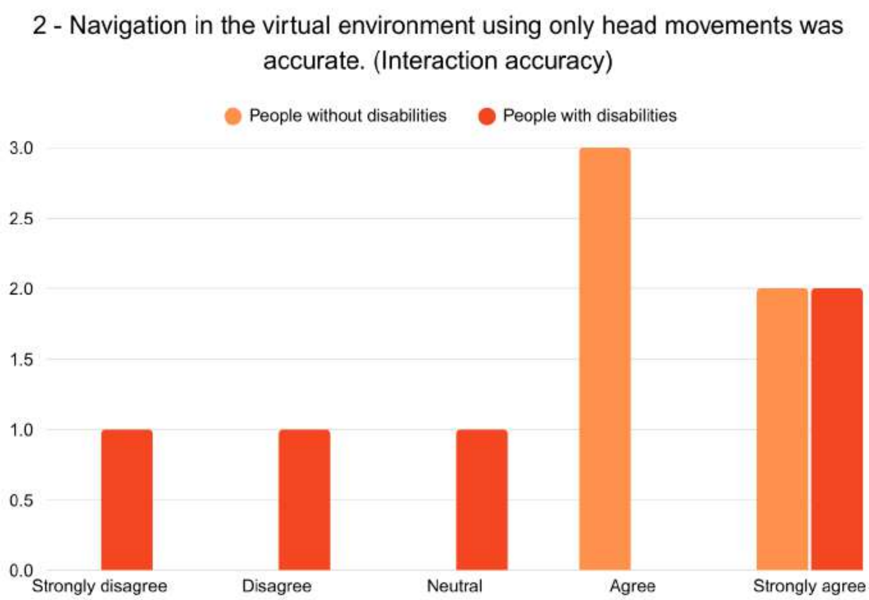


Figure 26: Main-Test - Question 2

In figure 27 is possible to notice that 70% of the participants quickly understood how the tasks worked. Even with the different cognitive levels of people with disabilities, the strongly agree option obtained the most points, with 4 out of 5 participants choosing this option. Regarding the accuracy of the choice of faces, in figure 28, the majority of people without disabilities had no problems navigating between the 6 faces of the cube and choosing the face indicated in the task, but due to the different levels of mobility of people with disabilities, it is possible to see that the numbers for this option for this group vary between practically all the options on the scale.

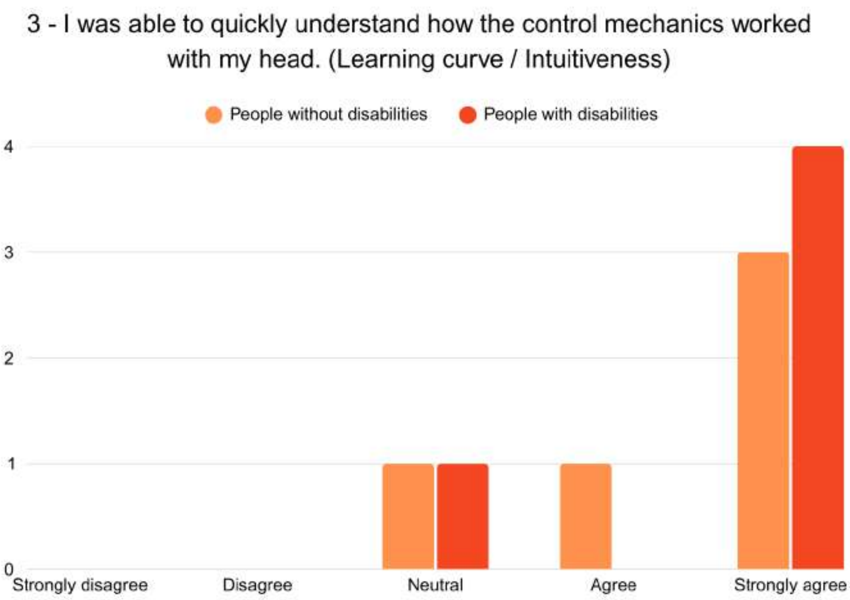


Figure 27: Main-Test - Question 3

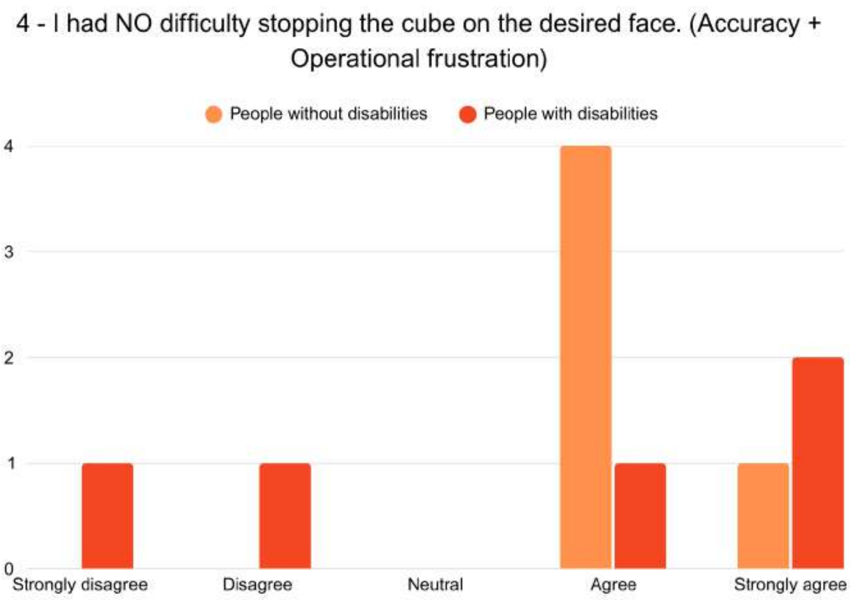


Figure 28: Main-Test - Question 4

The blow selection method was the favorite among people without disabilities, but among participants with disabilities, not all tried this option. Of the 5 participants with disabilities, 2 chose not to use this selection method, and 3 found the blow method easy to use (Figure 29). However, the method of aligning the cube face with the face (pause) was tested by all participants. Unlike the blow method, among people without disabilities, the values are divided between neutrality and absolute agreement that this is a good selection method (Figure 30).

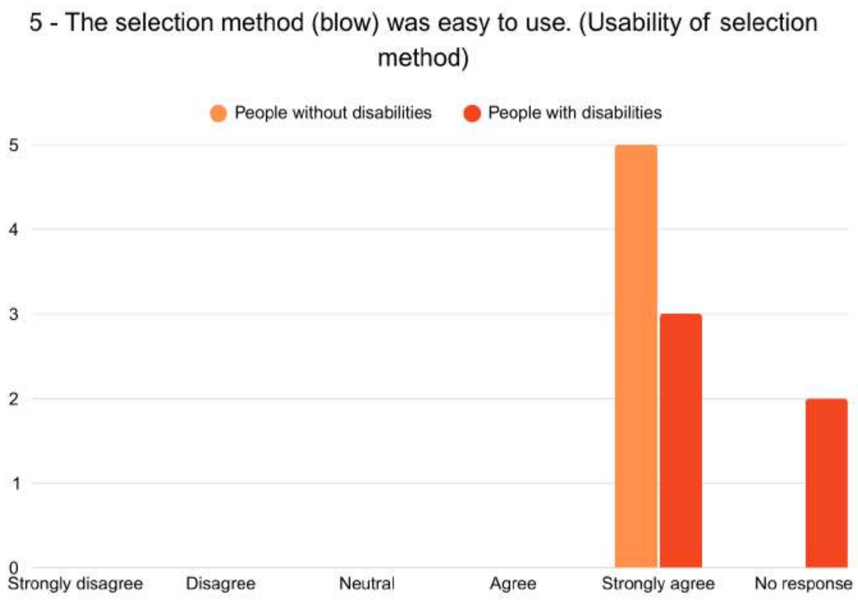


Figure 29: Main-Test - Question 5

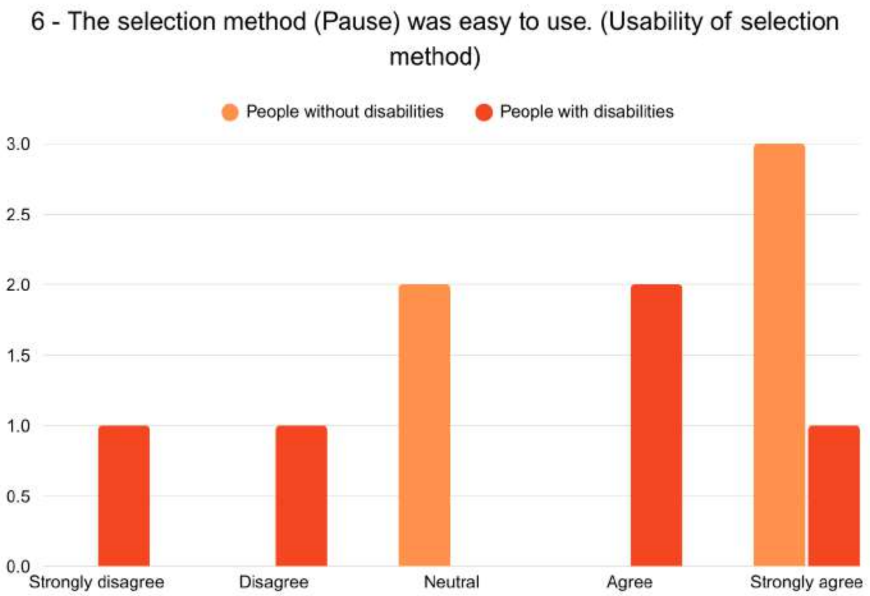


Figure 30: Main-Test - Question 6

In Figure 31, which evaluate cognitive load, it can be seen that both groups predominantly responded to the "Disagree" and "Neutral" options, suggesting that most did not perceive significant mental effort. The presence of "Strongly agree" responses only among people with disabilities indicates that this group may have experienced greater difficulty, although in small numbers.

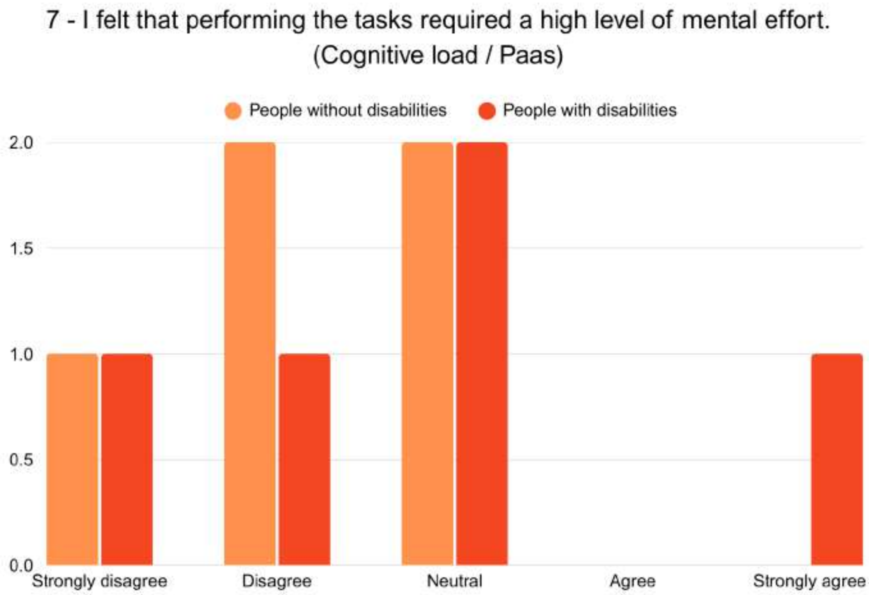


Figure 31: Main-Test - Question 7

Figure 32, on physical discomfort (cybersickness), shows that both people with and without disabilities overwhelmingly "Strongly disagree" or "Disagree" with the statement, indicating a low level of physical symptoms. These numbers indicate that the experience was generally cognitively accessible and physically comfortable for most participants, although people with disabilities reported slightly higher levels of mental effort and physical discomfort.

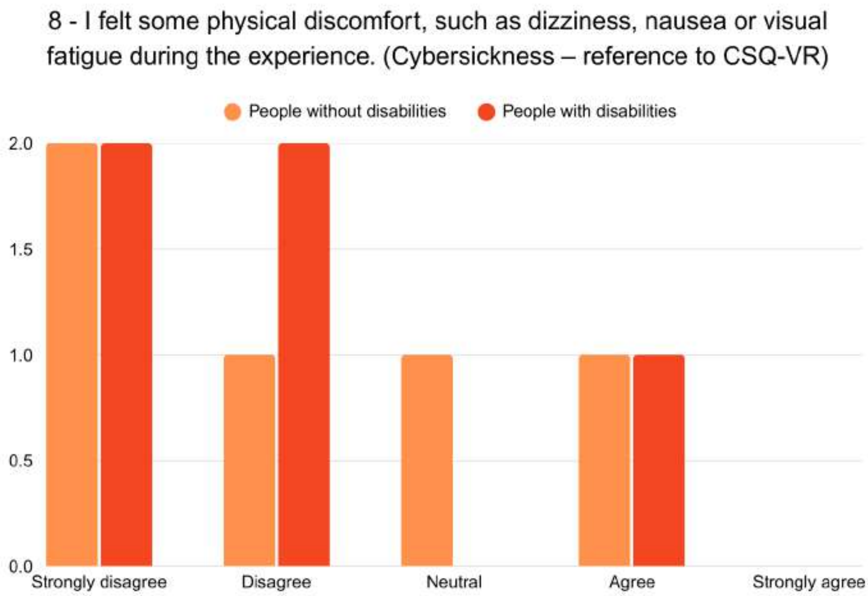


Figure 32: Main-Test - Question 8

The graph in Figure 33 indicates the level of frustration when using the head as the only means of control. The majority of participants, with and without disabilities, answered “Strongly disagree” regarding frustration, indicating that using the head as a control was not widely perceived as frustrating. However, some people with disabilities marked “Agree” and “Strongly agree”, which indicates that for part of this group, the method can generate some discomfort.

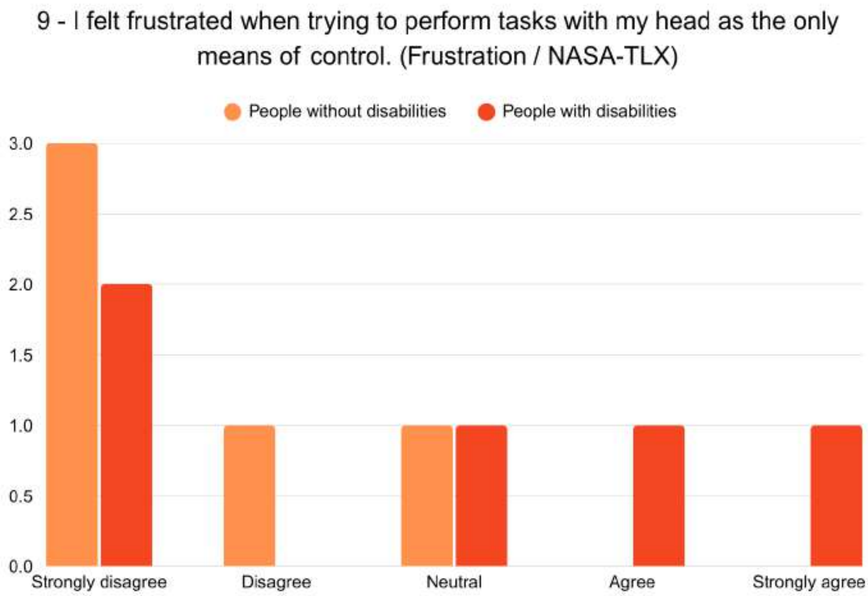


Figure 33: Main-Test - Question 9

Figure 34, which evaluates the perceived accessibility of this type of hands-only control, shows a very positive consensus on the usefulness of this control for people with motor limitations: almost all participants in both groups answered “Strongly agree”, with small variations in “Agree” and no negative responses. This suggests a much favorable perception of the NavHead VR accessibility, even among those who eventually felt some level of frustration, as indicated by the data in the previous graph.

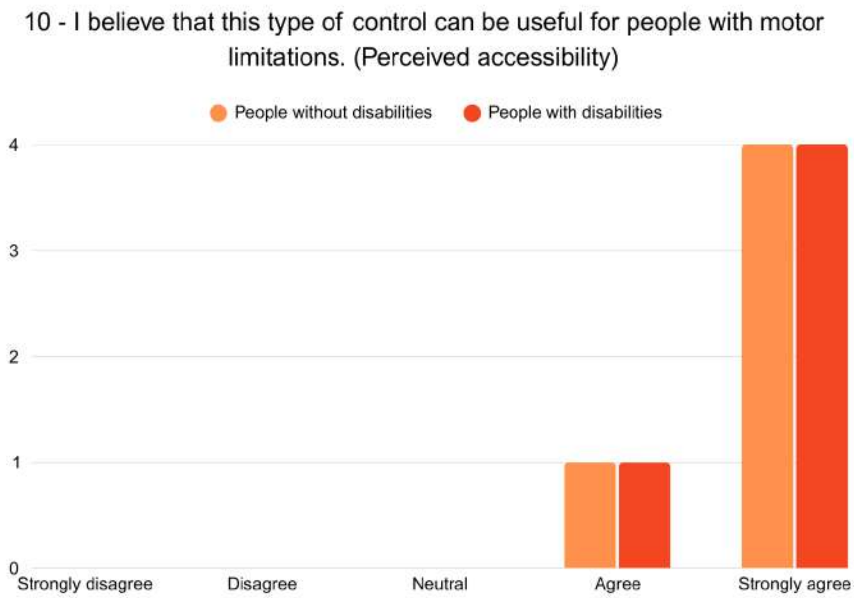


Figure 34: Main-Test - Question 10

Figures 35 and 36 analyze the participants' perception of the interface's respect for their choices (dignity/empathy) and the suitability of using head gestures for navigation. In Figure 35, the majority of non-disabled participants answered “Agree”, indicating that they felt their choices and pace were respected. Among people with disabilities, there is a more varied distribution: some “Disagree” and “Neutral” responses suggest that part of this group felt less empathy or flexibility from the interface. Even so, there are positive responses in “Agree” and “Strongly agree” among this group too, which indicates a mixed perception. In Figure 36, both groups showed strong acceptance of head gesture navigation: the majority - 60% - responded “Strongly agree”, with few negative responses (“Strongly disagree” and “Disagree”). This demonstrates a high degree of acceptance of the technology as a means of navigation.

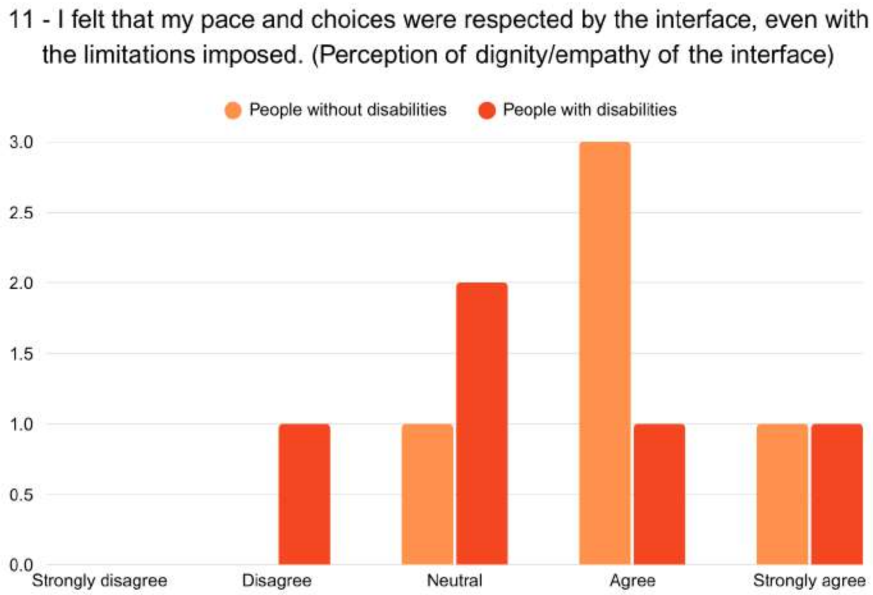


Figure 35: Main-Test - Question 11

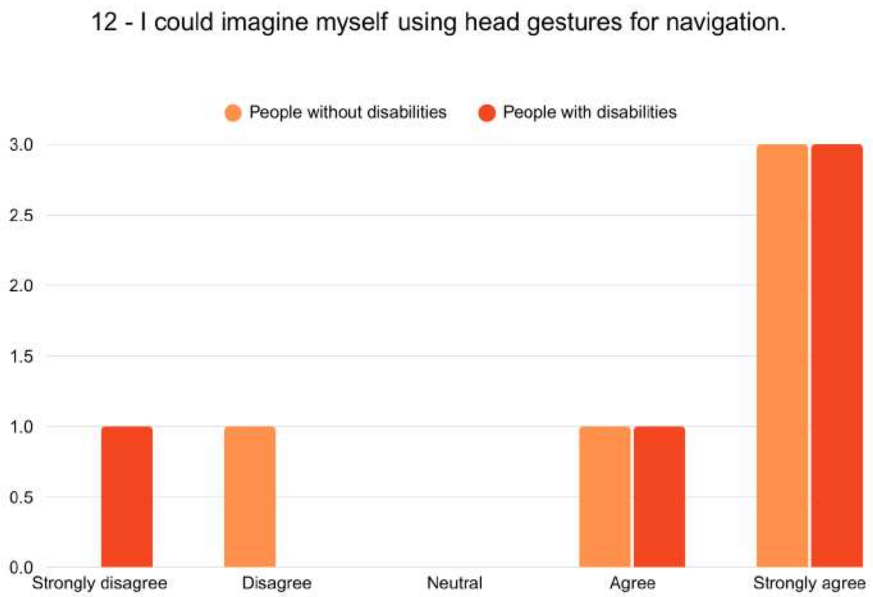


Figure 36: Main-Test - Question 12

7.4 Qualitative evaluation

The qualitative evaluation was divided between neurotypical individuals without physical disabilities and individuals with disabilities. This allowed the data to be used as a comparison between the two groups. The questions were the same as those used in the pre-test:

1. Describe in your own words what your experience was like using only head movements to interact with the virtual environment.
2. Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?
3. Do you have any suggestions for improving this type of head-only interaction?

7.4.1 People without disabilities

In this group, the reinforcement that the experience was positive appeared again. There was also the information that even though they were not used to the experience, it was an easy activity to understand and smooth, as the user needed only a few movements to reach the desired result. However, there were complaints about the frustration with the application. For example, one person felt frustrated because he said the application was uncomfortable on the eyes. Another participant felt frustrated when he had to turn more times than necessary to reach the desired face of the cube and complete the task. Another person felt confused by the up and down logic and the fact that the cube kept spinning even after they stopped making a move. Finally, there were also moments of frustration when the face of the cube was not selected after waiting 4 seconds, and the same person said that the rotation of the cube could be faster.

As a final suggestion, it was said that the rotation speed could be increased, and that the blowing method was very efficient. Another suggestion is that the 4-second time could be shorter and that the up and down logic could be the opposite. Other feedback was that the icon representing night mode was unclear.

7.4.2 People with disabilities

People with disabilities were unable to write their opinions. Some preferred to speak freely, without following the question script. Others gave their opinions while answering the quantitative questionnaire. Overall, it was said that the application takes some getting used to, but once accustomed, it's workable. However, even with getting used to it, the combination of this person's disabilities makes it difficult to use. Another person reported that the right- and left-hand direction was confusing. However, everyone said the idea would be useful for people with disabilities, although not for all types of disabilities. One participant even stated that voice control would be more practical for him. However, for those who cannot speak or move from the neck down, the glasses could be a great option. One participant even asked if she could buy the application because she lives alone, despite having a physical disability.

7.5 Task Execution Time per Participant without disability

As the tasks between the group of non-disabled people could be done following the research scope, it was possible to make some comparison graphs in terms of the time taken to complete the test activities. The first graph in figure 37 shows the total time in seconds that each non-disabled user took to do all the tasks, with the first and last tasks being the same (turning the instruction banner on/off), and the tasks between the first and last being randomized, including the selection mode by blowing or aligning the face.

In the graph, it can be seen that there is a discrepancy between participant 1 and participant 5, in which one took more than 7 min to complete the tasks, and the other took just over 2 min to complete the test. This indicates that within the same group of non-disabled people, there are different levels of understanding and ease with the application, especially considering the homogeneity in the way the test is applied to this group.

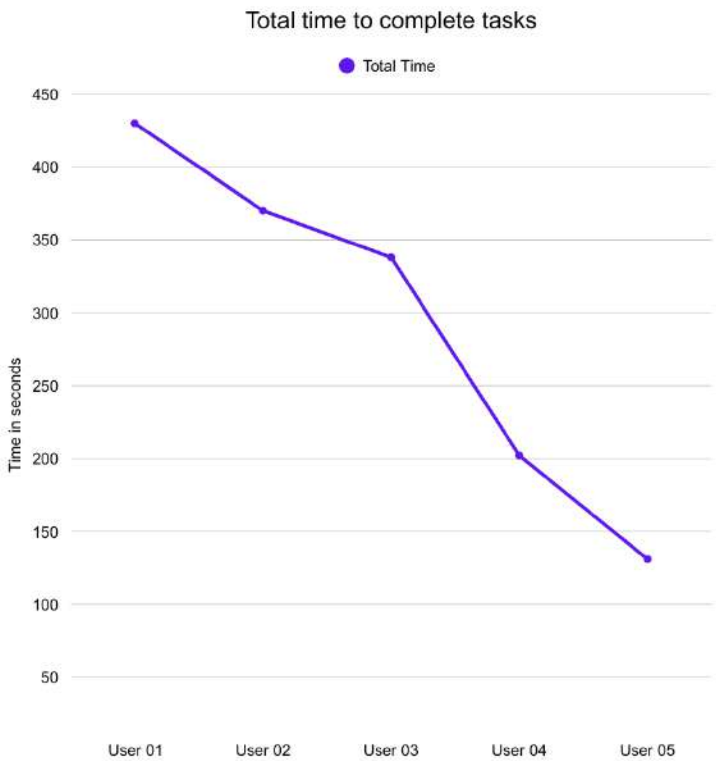


Figure 37: Total time to complete main-test tasks

Graph 38 compares the time to complete the first and last tasks. For all users, the time for the last task is shorter than that for the first, with the exception of a small variation in User 04. The difference is especially higher for User 01, who reduced the time from approximately 160 seconds to 100 seconds. This reinforces the idea of learning during application use, indicating that users were becoming familiar with the commands and the environment.

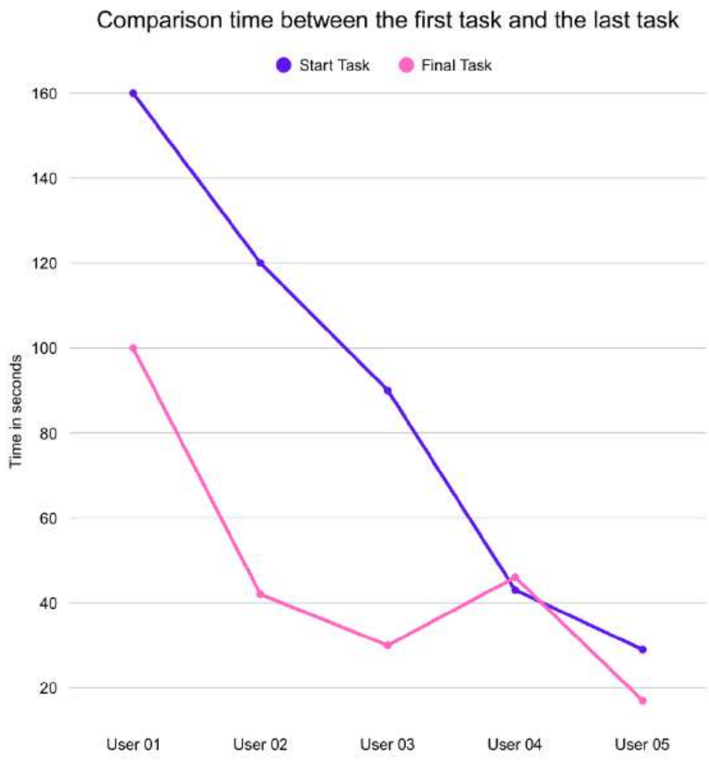


Figure 38: Time Comparison: Initial vs. Final Task

The graph below compares the time spent completing tasks using the blowing and face alignment methods (Figure 39). The time for face alignment is higher for the first three users (especially User 02), but drops dramatically for the last two. The time for blowing selection is more consistent, with a slight reduction for the last few users. This indicates that the face alignment task is more difficult, and the blowing selection task appears to have a better learning curve.

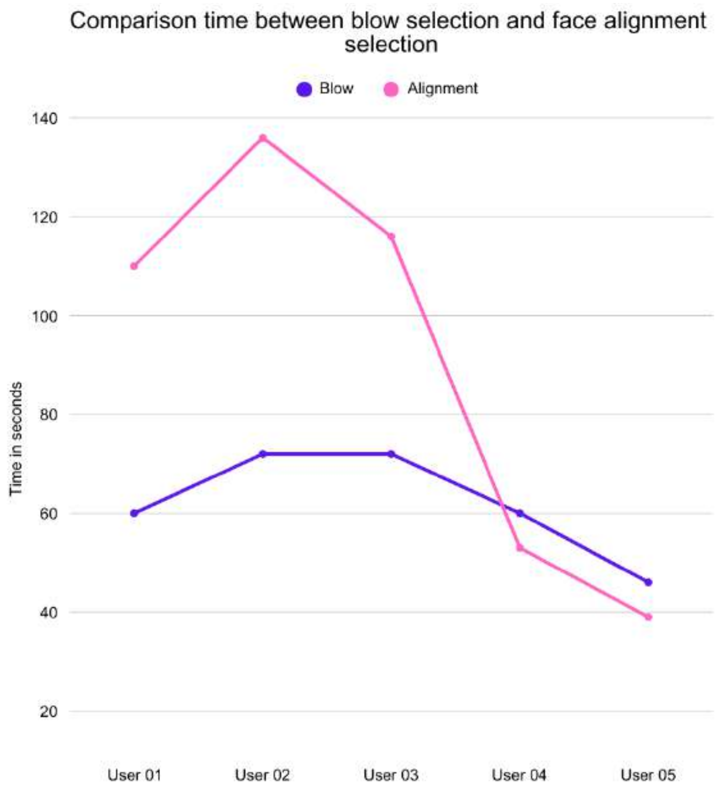


Figure 39: Selection Time: Blow vs. Face Alignment

8. Discussion

The goal of this study was to investigate the user experience of a virtual reality interface controlled solely by head movement, considering aspects of accessibility, accuracy, and usability efficiency between people with and without disabilities. The idea was to explore whether it's possible to create an inclusive VR environment for people with disabilities. Based on the initial research questions mentioned in section 3.2 of this study, some of the outcomes confirmed our expectations, while others were a little bit different.

Regarding the question: “Does the exclusive use of the head as a method of navigation in virtual reality provide a comfortable and understandable experience for the user?”, the hypothesis was that users would find head-only navigation comfortable and intuitive. The results, from both control groups, showed that the head-based method is indeed comfortable and easy to understand. However, it is not entirely intuitive, as participants reported a small degree of mental effort was required to complete the proposed tasks.

For the second question: “How accurate is the selection of elements in the virtual interface based solely on the positioning and rotation of the head?”, the goal was to assess whether the system could properly interpret users' input. The outcome showed that most participants felt the movements were interpreted accurately - especially favoring the blow selection method (among the 8 participants who tested it). However, the face alignment method, where the user aligns their face with the cube face to select, had more mixed feedback and was not the preferred method overall. Participants also pointed out - especially in the qualitative questionnaire - that the cube’s rotation accuracy was not always well-received. This was due to issues such as rotation speed or unexpected direction when performing certain movements. However, in most cases, this did not lead to user frustration.

The final question was: “Which selection method (e.g., 4-second pause or blow) is perceived as more natural, accessible, and effective by users?” The hypothesis was that one method would be clearly preferred by participants. As predicted, one option stood out: the blow selection method. Not only was it preferred by most users, but it also had a better average task completion time, with more consistent and concise data, particularly among users without disabilities. Additionally, among users with disabilities who experienced both selection modes, the majority also voted in favor of the blow method.

In terms of methodology, the testing process had several limitations - especially for the group with disabilities. The first limitation was logistical: because the test required a VR headset and a compatible computer setup, thus it wasn’t practicable to run large-scale tests. All the necessary devices had to be transported to an appropriate environment - well-lit, calm, and with space for a table and chair. Also, at various times the system presented bugs, either due to connection issues between the Meta Quest 3 and the PC or frequent software updates. Furthermore, the headset wouldn’t connect to the university’s Wi-Fi network. In some cases, the device needed an update to work properly, but the update required internet access, and since the headset couldn't connect to Wi-Fi on campus, it couldn’t always be updated in time or in place.

Another limitation affecting participants with disabilities was related to test structure. The tests were long and had too many steps, which meant that the protocol had to be adapted individually for each person. This showed that perhaps the tasks should have been more simplified. Still, because each participant had a different physical condition, even shorter tests wouldn’t necessarily be accessible to everyone. However, it was very important to see that the Navhead application responded well when participants with disabilities attempted a movement, whether it was yaw, pitch, or roll.

During development, one of the biggest technical challenges was preventing gesture overlap - when different head movements are interpreted at the same time. This was resolved by adjusting the “rotationThreshold”, which defines a minimum angle required to recognize a movement, and by comparing the intensity of the three head movements. This way, only the most intense movement was recognized, avoiding mix-ups between rotation, tilt, and zoom.

What didn't go as expected was the way test results had to be compared across both groups, despite the task structures not being exactly the same. Although feedback from people with disabilities was crucial to this study, using a structured test for one group and an unstructured test for the other added some limitations to data comparison. This could have been avoided by designing a different kind of task, with a single goal but multiple possible solutions, in a way that could accommodate a variety of disabilities. For example, avoiding tasks that require pitch specifically - since not all participants can perform that movement - and instead allowing the task to be completed using any of the three available head gestures: roll, yaw, or pitch.

Another point worth mentioning is that the Meta Quest 3 controllers are capable of much more: each has five buttons and a joystick. Depending on how the developer maps the inputs, at least three buttons can be used for selection, and the joystick itself offers a wider range of motion than head gestures, which are constrained by the anatomy of the human head. When a neurotypical person without a disability - especially someone already familiar with VR headsets and controllers - tests an application that uses only head movement, it's possible that they feel frustrated with Navhead, as their personal comparison favors the controller, which gives them more freedom and control in a virtual space.

On the other hand, watching people with disabilities experience a virtual world for the first time - and receiving their feedback that this form of control can truly help - made it clear that the research has value and potential for growth. Additionally, it became clear that VR can offer more freedom to people with motor limitations, whether through the control of a smart home or simply by allowing them to experience a world beyond the spatial boundaries they are used to. Another feedback received was that these applications can be useful in enabling people with severe motor disabilities to “travel” and “walk around” through the use of technology.

Unfortunately, within a 3-month period, it wouldn't be realistic to conduct a large number of tests, fully develop the application, and carry out all the theoretical research on the topic. But within that time, it was possible to verify some hypotheses and detect patterns that can serve as a foundation for future research.

9. Conclusion and Outlook

This study aimed to explore how virtual reality interfaces can be used through head movement and how this method can offer a more inclusive experience for people with and without disabilities. In order to create yet another method of inclusion in the available types of controllers in virtual reality environments. Over three months, the project resulted in theoretical research showing different kinds of accessibility gadgets, as well as the development and testing of Navhead, a VR application that allows the user to navigate and select objects using natural head gestures such as yaw, pitch, and roll.

Despite its limitations, the system demonstrated that alternative forms of interaction in virtual reality are not only possible but also relevant, especially when accessibility is considered from the start of the design process. However, it was also noticed that due to the different types of special needs, even within a group of people with the same type of disability, systems that promote accessibility should be customizable, so that within a group, they can work for a greater number of people.

The main findings showed that head movement control is generally comfortable and understandable, but not completely intuitive for all users. The method required a small amount of mental effort, especially at times when it was necessary to align the face with one of the cube faces or perform more precise gestures. Of the two selection methods tested (4 second pause and blow), the blow method was preferred by both groups, as it was faster and required less effort, especially among disabled users who were willing to test this function. Regarding the system's accuracy, head gestures recognition worked reasonably well, but issues related to rotation speed, overlapping axes, and unintentional interactions still affected the overall experience.

One of the main contributions of this work has been to show that it is possible to develop a simple VR interface that does not depend on physical controllers, but still allows meaningful interactions for people with reduced mobility. While systems based on traditional control offer more freedom and precision for non-disabled users, Navhead presents an alternative that can help include more people in the world of virtual reality, including those who would normally be excluded. It was especially great to see disabled participants successfully interacting with the system and providing direct feedback that “this can really help people like me”.

From a practical point of view, applications such as Navhead could be improved in the future for use in areas such as rehabilitation, assistive technology, leisure, or inclusive educational platforms. A VR system that responds to head gestures could help train cervical mobility, enable non-verbal interaction for people with speech limitations, or serve as an accessible interface for cognitive tasks in immersive environments.

Even so, the methodology adopted faced important limitations, especially in the group of participants with disabilities. As mentioned in the previous chapter, one of the main difficulties was the need to adapt the tests individually, which showed that perhaps the proposed tasks should have been simplified from the start. However, as each participant had very specific physical conditions, even with shorter tests, not all gestures would be possible. On the other hand, whenever the participants were able to perform a movement (yaw, pitch, or roll), the application was very responsive. This was reflected in the way the two groups of participants were compared, as the tasks did not have the same structure. Although the feedback from people with disabilities was essential for this study, the use of a structured test for one group and an unstructured one for the other brought limitations to the comparative analysis.

In the future, some points could be improved in the NavHead application, in the Meta Quest system itself, and VR headsets in general. As mentioned in the literature survey for this study, several accessibility devices could be used as a controller for virtual reality glasses. However, headsets are not built to accept these devices directly, requiring a whole hardware structure to be able to connect the glasses to possible accessibility devices with powerful computers. This is not possible for most people. In addition, the headsets themselves are heavy, which can make them difficult to use daily. One way to solve these problems would be to think of accessibility not as something adjacent, but as a starting point in developing the interface and evaluating the user experience.

As for the NavHead application itself, the improvements would concern the possibility of a more customizable interface that can serve to a greater number of people with and without disabilities. Because the possibility of using this type of technology goes beyond providing inclusion for people with walking impediment, but also provides a greater possibility of controls that can be used for games, learning, therapies, in the industry, among others. Finally, the need to test this type of controller with a larger number of people is also important, in order to discover the different environments in which this type of application would be useful and necessary, without losing focus on being accessible, accurate, and efficient for all users.

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11. Attachments

11.1 Pre-Test demographic data graphics

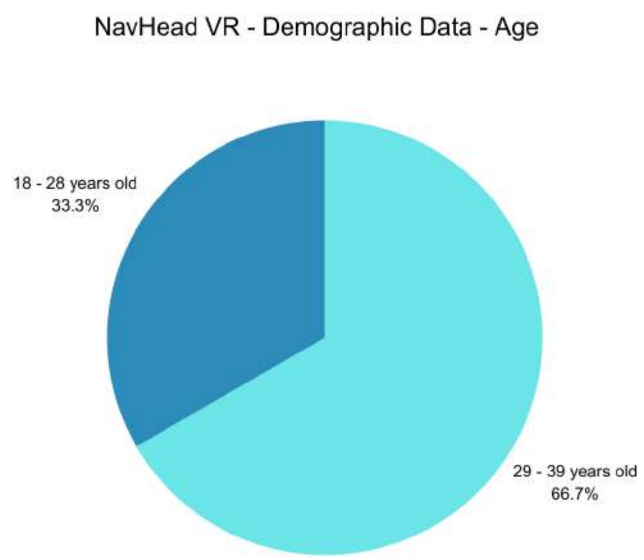


Figure 40: Pre-Test - demographic data - age

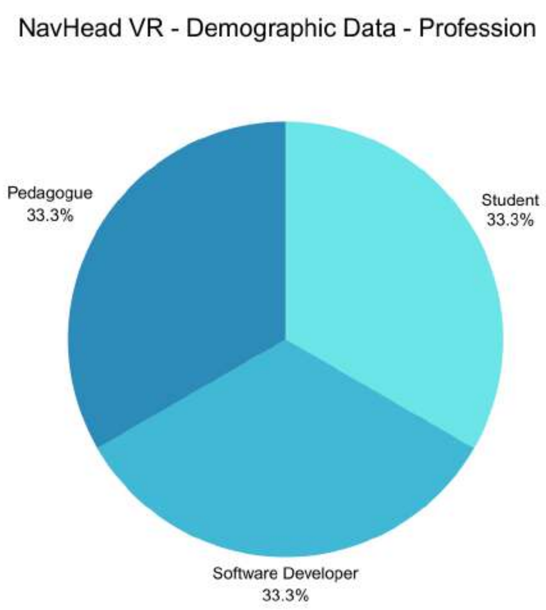


Figure 41: Pre-Test - demographic data - profession

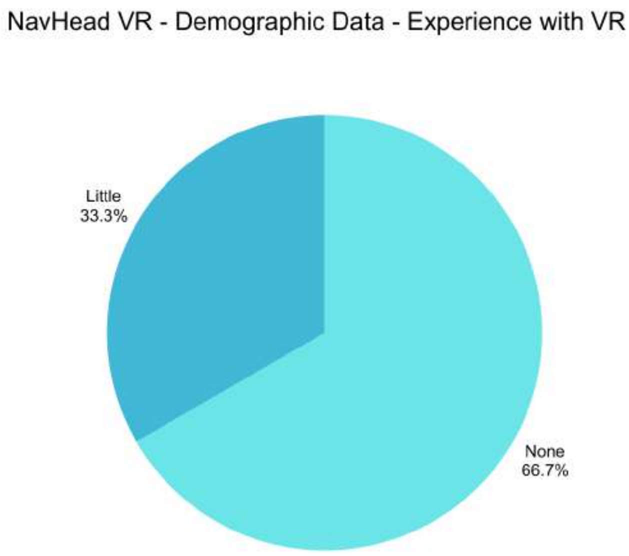


Figure 42: Pre-Test - demographic data - VR experience

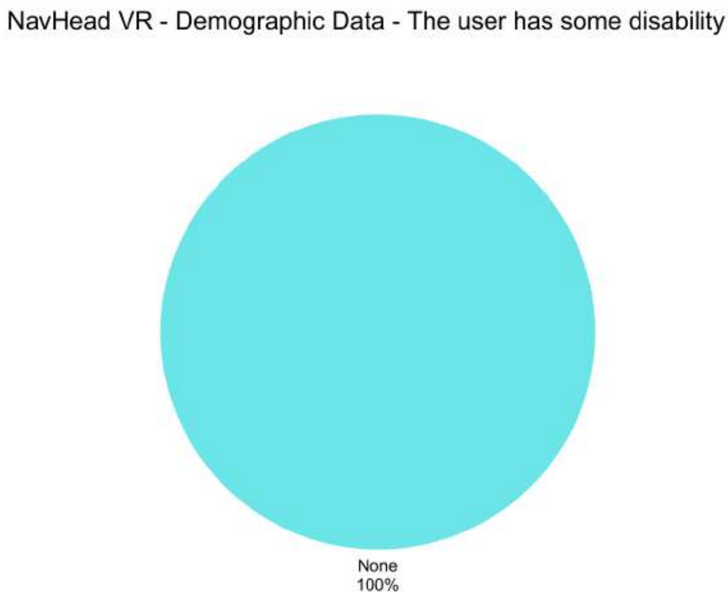


Figure 43: Pre-Test - demographic data - participants with disability

11.2 Main-Test demographic data graphics

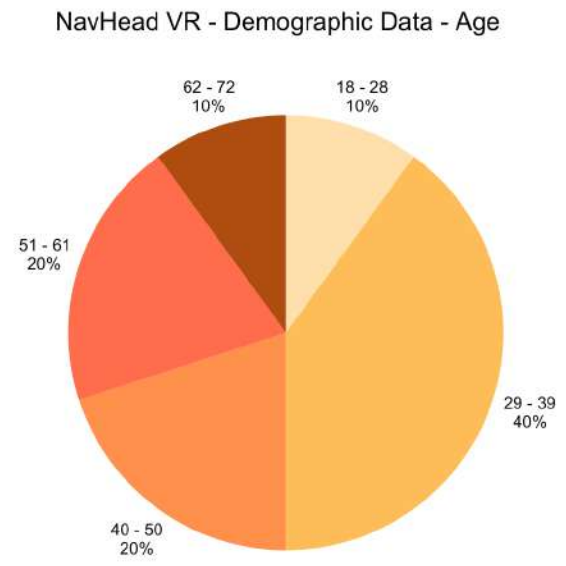


Figure 44: Main-Test - demographic data - age

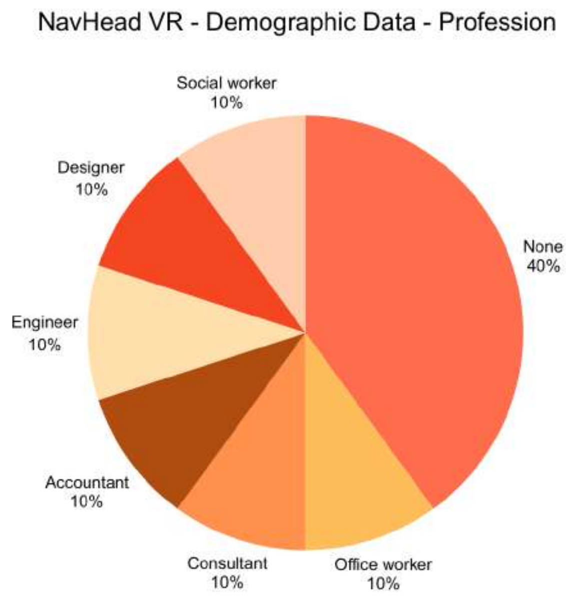


Figure 45: Pre-Test - demographic data - profession

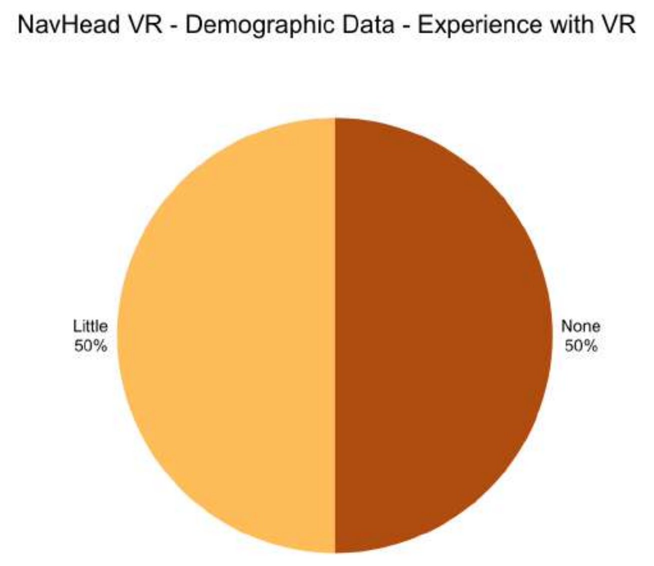


Figure 46: Pre-Test - demographic data - VR experience

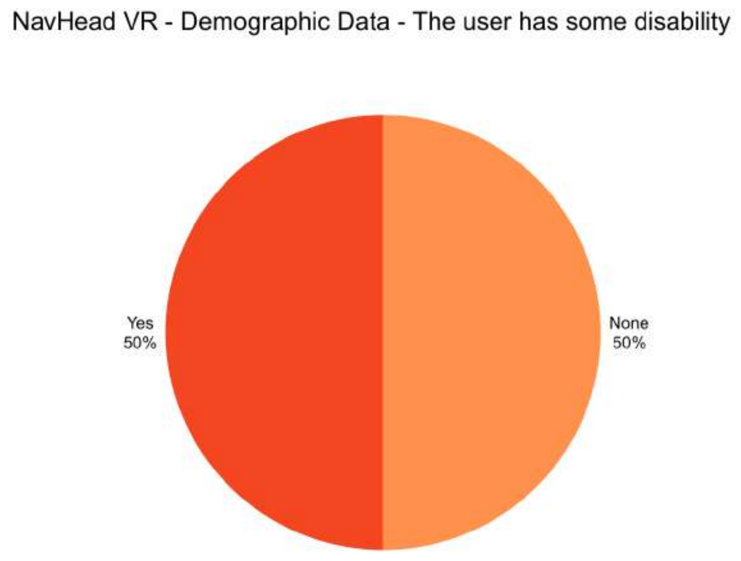


Figure 47: Pre-Test - demographic data - participants with disability

11.3 Questionnaires

11.3.1 Pre-Test questionnaires

NavHead VR - Demographic Data

Gender / Geschlecht:

☒ M ☐ F ☐ Other / Andere

Age / Alter: 30

Profession / Beruf: Pädagoge

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Nein

Pre-Test questionnaire 1 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu 1	2	3	4	Stimme voll und ganz zu 5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).			X			1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)			X			2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)		X				4
5 - Die Auswahlmethode (**Auswahlmethode per Atemstoß**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode) Pusten				X		5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)		X				6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)			X			7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)	X					8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)		X				9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)		X				11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.				X		12

Pre-Test questionnaire 1 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

Es ist am Anfang ein bisschen unangehm, aber sobald man versteht wie es geht, dann geht's relativ einfach.

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

nein.

3 – Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

Seine rollen fähigkeit könnte verbessert werden

- [ ] Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.
- [ ] Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

Stuttgart, 11.06.25

Place, Date

Pre-Test questionnaire 1 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☒ M ☐ F ☐ Other / Andere

Age / Alter: 35

Profession / Beruf: SW - Entwickler

Experience with VR / Erfahrung mit VR:

☐ None / Keiner ☒ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Nein

Pre-Test questionnaire 2 - demographic data

NavHead VR - Questionnaire (EN)

	Strongly disagree 1	2	3	4	Strongly agree 5	
1 - I felt that using only my head to control the interface was comfortable. (Physical comfort / Cybersickness).				X		1
2 - Navigation in the virtual environment using only head movements was accurate. (Interaction accuracy)			X			2
3 - I was able to quickly understand how the control mechanics worked with my head. (Learning curve / Intuitiveness)			X			3
4 - I had **NO** difficulty stopping the cube on the desired face. (Accuracy + Operational frustration)					X	4
5 - The selection method (**blow**) was easy to use. (Usability of selection method)			X			5
6 - The selection method (**Pause**) was easy to use. (Usability of selection method)				X		6
7 - I felt that performing the tasks required a high level of mental effort. (Cognitive load / Paas)			X			7
8 - I felt some physical discomfort, such as dizziness, nausea or visual fatigue during the experience. (Cybersickness – reference to CSQ-VR)			X			8
9 - I felt frustrated when trying to perform tasks with my head as the only means of control. (Frustration / NASA-TLX)			X			9
10 - I believe that this type of control can be useful for people with motor limitations. (Perceived accessibility)					X	10
11 - I felt that my pace and choices were respected by the interface, even with the limitations imposed. (Perception of dignity/empathy of the interface)		X				11
12 - I could imagine myself using head gestures for navigation.				X		12

Pre-Test questionnaire 2 - quantitative

NavHead VR - Questionnaire (EN)

1 - Describe in your own words what your experience was like using only head movements to interact with the virtual environment.

Better than expected. Some movements worked better than others

2 - Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?

Yes, I could not make the cube spin vertically

3 - Do you have any suggestions for improving this type of head-only interaction?

Make the cube spin faster

- [x] I hereby voluntarily consent to the anonymous processing of my data on the questionnaire as part of the research and may be published.
- [ ] I **do not** consent to the processing of my data on the questionaire as part of the research

Stuttgart, 13.06.25

Place, Date

Pre-Test questionnaire 2 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 21

Profession / Beruf: Studentin

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Pre-Test questionnaire 3 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu				Stimme voll und ganz zu	
	1	2	3	4	5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).					X	1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)				X		2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)				X		4
5 - Die Auswahlmethode (~~**Auswahlmethode per Atemstoß**~~) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)			X			6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)		X				7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)	X					8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)		X				9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)					X	11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.					X	12

Pre-Test questionnaire 3 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

Ungewöhnlich, aber man hat sich schnell dran gewöhnt und ab dann war es einfach zu bedienen

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

Bei der Auswahl bei der man einfach nur den Kopf still halten sollte, war ich zunächst verwirrt inwiefern ich den Kopf stillhalten soll

3 – Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

/

- [x] Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.
- [x] Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

Schwabenbach, 14.6.25

Place, Date

Pre-Test questionnaire 3 - qualitative

11.3.2 Main Test Questionnaires

11.3.2.1 People without special needs

NavHead VR - Demographic Data

Gender / Geschlecht:

☒ M ☐ F ☐ Other / Andere

Age / Alter: 35

Profession / Beruf: Consultant

Experience with VR / Erfahrung mit VR:

☐ None / Keiner ☒ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Nein

Main-Test questionnaire 1 - demographic data

NavHead VR - Questionnaire (EN)

	Strongly disagree 1	2	3	4	Strongly agree 5	
1 - I felt that using only my head to control the interface was comfortable. (Physical comfort / Cybersickness).			X			1
2 - Navigation in the virtual environment using only head movements was accurate. (Interaction accuracy)				X		2
3 - I was able to quickly understand how the control mechanics worked with my head. (Learning curve / Intuitiveness)				X		3
4 - I had **NO** difficulty stopping the cube on the desired face. (Accuracy + Operational frustration)				X		4
5 - The selection method (**blow**) was easy to use. (Usability of selection method)					X	5
6 - The selection method (**Pause**) was easy to use. (Usability of selection method)			X			6
7 - I felt that performing the tasks required a high level of mental effort. (Cognitive load / Paas)				X		7
8 - I felt some physical discomfort, such as dizziness, nausea or visual fatigue during the experience. (Cybersickness – reference to CSQ-VR)		X				8
9 - I felt frustrated when trying to perform tasks with my head as the only means of control. (Frustration / NASA-TLX)			X			9
10 - I believe that this type of control can be useful for people with motor limitations. (Perceived accessibility)					X	10
11 - I felt that my pace and choices were respected by the interface, even with the limitations imposed. (Perception of dignity/empathy of the interface)				X		11
12 - I could imagine myself using head gestures for navigation.				X		12

Main-Test questionnaire 1 - quantitative

NavHead VR - Questionnaire (EN)

1 - Describe in your own words what your experience was like using only head movements to interact with the virtual environment.

The experience was positiv as my head movements were registered and turned the cube. What did not work, was waiting for 4 seconds

2 - Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?

When the system didn't accept my 4 sec of waiting to confirm. And the cube could turn a bit faster.

3 - Do you have any suggestions for improving this type of head-only interaction?

The speed could be adjusted. Blowing for confirmation works fine. Or a controller (joystick) could be used for confirmation.

☒ I hereby voluntarily consent to the anonymous processing of my data on the questionnaire as part of the research and may be published.

☐ I **do not** consent to the processing of my data on the questionaire as part of the research

Reutlingen, 06.07.2025

Place, Date

Main-Test questionnaire 1 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 29

Profession / Beruf: Buchhalterin

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Nein

Main-Test questionnaire 2 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu 1	2	3	4	Stimme voll und ganz zu 5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).			X			1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)				X		2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)				X		4
5 - Die Auswahlmethode **(Pusten)** war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)			X			6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)			X			7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)				X		8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)		X				9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)				X		11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.		X				12

Main-Test questionnaire 2 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

Ungewohnt, jedoch einfach und schnell verständlich

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

Ich war kurz verwirrt als ich nicht schnell genug meine Kopfbewegung beendet und sich der Würfel bereits weiterbewegt hat

3 - Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

Pausen durch eine Kopfbewegung oder das Pusten ersetzen

- [x] Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.
- [ ] Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

Reutlingen 06.07.2025

Place, Date

Main-Test questionnaire 2 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☒ M ☐ F ☐ Other / Andere

Age / Alter: 32

Profession / Beruf: Engineer

Experience with VR / Erfahrung mit VR:

☐ None / Keiner ☒ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

No, No

Main-Test questionnaire 3 - demographic data

NavHead VR - Questionnaire (EN)

	Strongly disagree 1	2	3	4	Strongly agree 5	
1 - I felt that using only my head to control the interface was comfortable. (Physical comfort / Cybersickness).					✓	1
2 - Navigation in the virtual environment using only head movements was accurate. (Interaction accuracy)					✓	2
3 - I was able to quickly understand how the control mechanics worked with my head. (Learning curve / Intuitiveness)			✓			3
4 - I had **NO** difficulty stopping the cube on the desired face. (Accuracy + Operational frustration)				✓		4
5 - The selection method (**blow**) was easy to use. (Usability of selection method)					✓	5
6 - The selection method (**Pause**) was easy to use. (Usability of selection method)					✓	6
7 - I felt that performing the tasks required a high level of mental effort. (Cognitive load / Paas)	✓					7
8 - I felt some physical discomfort, such as dizziness, nausea or visual fatigue during the experience. (Cybersickness – reference to CSQ-VR)	✓					8
9 - I felt frustrated when trying to perform tasks with my head as the only means of control. (Frustration / NASA-TLX)	✓					9
10 - I believe that this type of control can be useful for people with motor limitations. (Perceived accessibility)					✓	10
11 - I felt that my pace and choices were respected by the interface, even with the limitations imposed. (Perception of dignity/empathy of the interface)				✓		11
12 - I could imagine myself using head gestures for navigation.					✓	12

Main-Test questionnaire 3 - quantitative

NavHead VR - Questionnaire (EN)

1 - Describe in your own words what your experience was like using only head movements to interact with the virtual environment.

It was easy and comfortable.

2 - Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?

The only confusion was the up and down logic.

3 - Do you have any suggestions for improving this type of head-only interaction?

I think the timer of 4sec could be lower and the up and down logic should be the opposite

☒ I hereby voluntarily consent to the anonymous processing of my data on the questionnaire as part of the research and may be published.

☐ I **do not** consent to the processing of my data on the questionaire as part of the research

Waiblingen, 04.06.25
Place, Date

Main-Test questionnaire 3 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

- [ ] M
- [x] F
- [ ] Other / Andere

Age / Alter: 34

Profession / Beruf: Designer

Experience with VR / Erfahrung mit VR:

- [x] None / Keiner
- [ ] Little / Wenig
- [ ] Moderate / Mäßig
- [ ] Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

nein

Main-Test questionnaire 4 - demographic data

NavHead VR - Questionnaire (EN)

	Strongly disagree				Strongly agree	
1 - I felt that using only my head to control the interface was comfortable. (Physical comfort / Cybersickness).	1	2	3	4	5	1
2 - Navigation in the virtual environment using only head movements was accurate. (Interaction accuracy)	1	2	3	4	5	2
3 - I was able to quickly understand how the control mechanics worked with my head. (Learning curve / Intuitiveness)	1	2	3	4	5	3
4 - I had **NO** difficulty stopping the cube on the desired face. (Accuracy + Operational frustration)	1	2	3	4	5	4
5 - The selection method (**blow**) was easy to use. (Usability of selection method)	1	2	3	4	5	5
6 - The selection method (**Pause**) was easy to use. (Usability of selection method)	1	2	3	4	5	6
7 - I felt that performing the tasks required a high level of mental effort. (Cognitive load / Paas)	1	2	3	4	5	7
8 - I felt some physical discomfort, such as dizziness, nausea or visual fatigue during the experience. (Cybersickness - reference to CSQ-VR)	1	2	3	4	5	8
9 - I felt frustrated when trying to perform tasks with my head as the only means of control. (Frustration / NASA-TLX)	1	2	3	4	5	9
10 - I believe that this type of control can be useful for people with motor limitations. (Perceived accessibility)	1	2	3	4	5	10
11 - I felt that my pace and choices were respected by the interface, even with the limitations imposed. (Perception of dignity/empathy of the interface)	1	2	3	4	5	11
12 - I could imagine myself using head gestures for navigation.	1	2	3	4	5	12

Main-Test questionnaire 4 - quantitative

NavHead VR - Questionnaire (EN)

1 - Describe in your own words what your experience was like using only head movements to interact with the virtual environment.

It was easy and quickly to unverstand .

2 - Was there a time or task when you felt frustrated, confused, or uncomfortable? If yes, why?

Yes, when I scrollen the cube more time then I needed.

3 - Do you have any suggestions for improving this type of head-only interaction?

The night icon is not clean what means.

- [x] I hereby voluntarily consent to the anonymous processing of my data on the questionnaire as part of the research and may be published.
- [ ] I **do not** consent to the processing of my data on the questionaire as part of the research

Waiblingen, 03.07.25

Place, Date

Main-Test questionnaire 4 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 18

Profession / Beruf: ______

Experience with VR / Erfahrung mit VR:

☐ None / Keiner ☒ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Main-Test questionnaire 5 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu				Stimme voll und ganz zu	
	1	2	3	4	5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).				X		1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)					X	2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)					X	4
5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)		X				7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)			X			8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)	X					9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)				X		10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)			X			11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.					X	12

Main-Test questionnaire 5 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

entspannt, weil man nur geringe Bewegungen machen musste

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

· es ist etwas anstrengend für meine Augen gewesen

3 – Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

☒ Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.

☐ Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

Stuttgart, 8.07.25

Place, Date

Main-Test questionnaire 5 - qualitative

11.3.2.2 People with special needs

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 66

Profession / Beruf: ______

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Spastisch Lähmung von Geburt

Main-Test questionnaire 6 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu				Stimme voll und ganz zu	
	1	2	3	4	5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).			X			1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)		X				2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)	X					4
5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)						5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)		X				6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)			X			7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)				X		8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)				X		9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)				X		11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.	X					12

Main-Test questionnaire 6 - quantitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 50

Profession / Beruf: ______

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Main-Test questionnaire 7 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu 1	2	3	4	Stimme voll und ganz zu 5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).					X	1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)					X	2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)					X	4
~~5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)~~						5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)	X					7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)	X					8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)	X					9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)					X	11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.					X	12

Main-Test questionnaire 7 - quantitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 58

Profession / Beruf: –

Experience with VR / Erfahrung mit VR:

☒ None / Keiner ☐ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Körperbehindert.

Main-Test questionnaire 8 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu 1	2	3	4	Stimme voll und ganz zu 5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).					X	1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)			X			2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)				X		4
5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)				X		6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)					X	7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)		X				8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)			X			9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)		X				11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.					X	12

Main-Test questionnaire 8 - quantitative

NavHead VR - Demographic Data

Gender / Geschlecht:

- [x] M
- [ ] F
- [ ] Other / Andere

Age / Alter: 40

Profession / Beruf: Bürokraft

Experience with VR / Erfahrung mit VR:

- [ ] None / Keiner
- [x] Little / Wenig
- [ ] Moderate / Mäßig
- [ ] Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Spastich und Sehbehinderung

Main-Test questionnaire 9 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu				Stimme voll und ganz zu	
	1	2	3	4	5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).	X					1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)	X					2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)			X			3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)		X				4
5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)	X					6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)			X			7 ABER DANACH
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)	X					8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)					X	9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)					X	10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)			X			11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.					X	12

Main-Test questionnaire 9 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

Gewöhnungsbedürfnis aber mit Übung machbar

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

Meine Einschränkungskombi mit dieser Bedienung macht es schwierig

3 – Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

Nein

- [x] Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.
- [ ] Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

08.08.2025, Stuttgart

Place, Date

Main-Test questionnaire 9 - qualitative

NavHead VR - Demographic Data

Gender / Geschlecht:

☐ M ☒ F ☐ Other / Andere

Age / Alter: 56

Profession / Beruf: Sozialpädagogin

Experience with VR / Erfahrung mit VR:

☐ None / Keiner ☒ Little / Wenig ☐ Moderate / Mäßig ☐ Extensive / Umfangreich

(Optional) Do you have any kind of disability (e.g., related to mobility or motor skills)? If yes, please describe.

(Optional) Haben Sie eine Form von Behinderung (z. B. in Bezug auf Mobilität oder motorische Fähigkeiten)? Wenn ja, welche?

Chronische Polyarthritis mit Bewegungseinschränkungen

Main-Test questionnaire 10 - demographic data

NavHead VR - Questionnaire (DE)

	Stimme überhaupt nicht zu				Stimme voll und ganz zu	
	1	2	3	4	5	
1 - Ich empfand es als angenehm, die Schnittstelle nur mit dem Kopf zu steuern. (Körperlicher Komfort / Cyberkrankheit).					X	1
2 - Die Navigation in der virtuellen Umgebung nur durch Kopfbewegungen war präzise. (Interaktionsgenauigkeit)					X	2
3 - Ich konnte schnell verstehen, wie die Steuerungsmechanik mit meinem Kopf funktioniert. (Lernkurve / Intuition)					X	3
4 - Ich hatte **KEINE** Schwierigkeiten, den Würfel auf der gewünschten Seite anzuhalten. (Genauigkeit + Bedienungsfrust)					X	4
5 - Die Auswahlmethode (**Pusten**) war einfach anzuwenden. (Benutzerfreundlichkeit der Auswahlmethode)					X	5
6 - Die Auswahlmethode (**Pause**) war einfach zu verwenden. (Benutzerfreundlichkeit der Auswahlmethode)				X		6
7 - Ich hatte das Gefühl, dass die Ausführung der Aufgaben ein hohes Maß an geistiger Anstrengung erforderte. (Kognitive Belastung / Paas)		X				7
8 - Ich habe während des Erlebnisses körperliche Beschwerden wie Schwindel, Übelkeit oder visuelle Ermüdung verspürt. (Cyberkrankheit – Bezug auf CSQ-VR)		X				8
9 - Ich war frustriert, wenn ich versuchte, Aufgaben zu erledigen, bei denen mein Kopf das einzige Kontrollmittel war. (Frustration / NASA-TLX)	X					9
10 - Ich glaube, dass diese Art der Steuerung für Menschen mit motorischen Einschränkungen nützlich sein kann. (Wahrgenommene Zugänglichkeit)				X		10
11 - Ich hatte das Gefühl, dass mein Tempo und meine Entscheidungen von der Benutzeroberfläche trotz der auferlegten Einschränkungen respektiert wurden. (Wahrnehmung der Würde/Empathie der Benutzeroberfläche)			X			11
12 - Ich könnte mir vorstellen, Kopfgesten zur Navigation zu verwenden.				X		12

Main-Test questionnaire 10 - quantitative

NavHead VR - Questionnaire (DE)

1 - Beschreiben Sie in Ihren eigenen Worten, wie es für Sie war, nur durch Kopfbewegungen mit der virtuellen Umgebung zu interagieren.

2 - Gab es einen Moment oder eine Aufgabe, bei der Sie sich frustriert, verwirrt oder unwohl fühlten? Wenn ja, warum?

3 – Haben Sie Vorschläge zur Verbesserung dieser Art der reinen Kopfinteraktion?

Richtung: Wenn Kopf links
dreht es rechts. Gleiche Richtung
wäre besser

- [x] Ich willige hiermit freiwillig ein, dass meine Angaben aus dem Fragebogen im Rahmen der Befragung anonymisiert verarbeitet und ggf. veröffentlicht werden.
- [ ] Ich bin mit der Verarbeitung meiner Daten im Fragebogen im Rahmen der Studie **nicht** einverstanden.

Stuttgart 08.07.2025

Place, Date

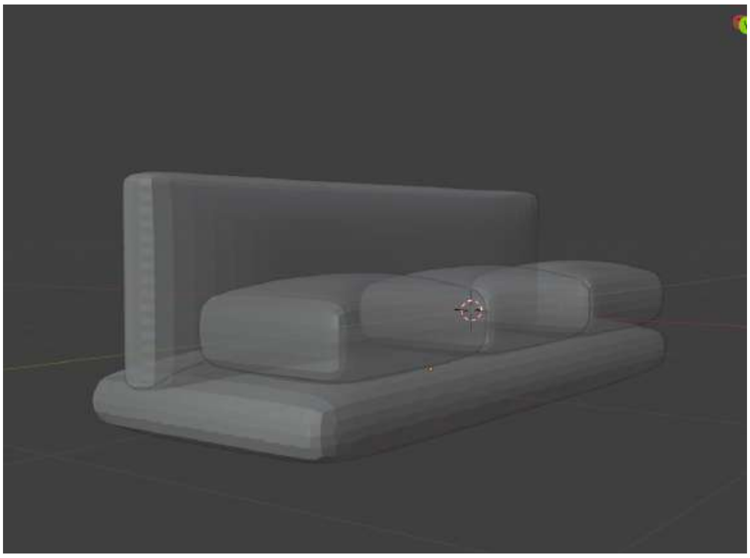
Main-Test questionnaire 10 - Qualitative

11.4 Assets

11.4.1 Blender assets

All the assets (game objects), except the images of the external environment and the television, were created exclusively for this research using Blender or Unity 3D. The assets and environment were created in low poly with textures to create a feeling closer to reality, but still with the intention of looking like a virtual environment that is not 100% realistic.

The 3D sofa model was created in Blender using basic cubes as the starting geometry. To refine the shape, Loop Cut and Slide tools were applied for subdivision, and the Subdivision Surface modifier was added to give the model a puffier, more realistic appearance. A cloth simulation was used to generate a soft cushion effect, enhanced further using the Sculpt Mode (Cloth Brush) to simulate fabric deformation. To improve visual quality, a Smooth shading filter was also applied. For the materials, a high-resolution leather texture from Poly Haven was used for the sofa's upholstery (Poly Haven, 2025a), while the legs of the sofa were textured with a wood veneer material, also from Poly Haven (2025b). These procedural and textural steps contributed to creating a realistic and visually cohesive furniture piece.



Sofa Blender 1 (personal file)

Sofa Blender 2 (personal file)

Sofa Blender 3 (personal file)

Sofa Blender 4 (personal file)

The table was made with three cylinders, one for the base on the floor, one for the foot of the table and one for the top of the table itself. The texture of the table was oak veneer from Poly Haven (2025b).

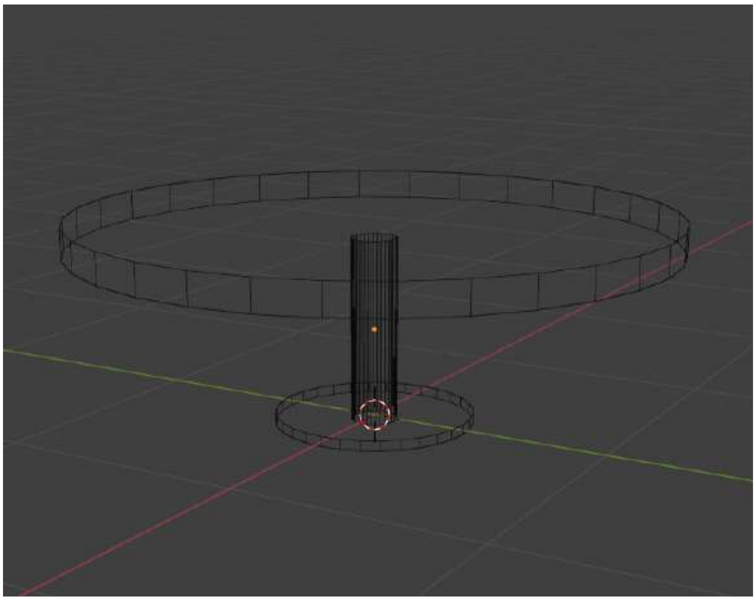


Table Blender 1 (personal file)

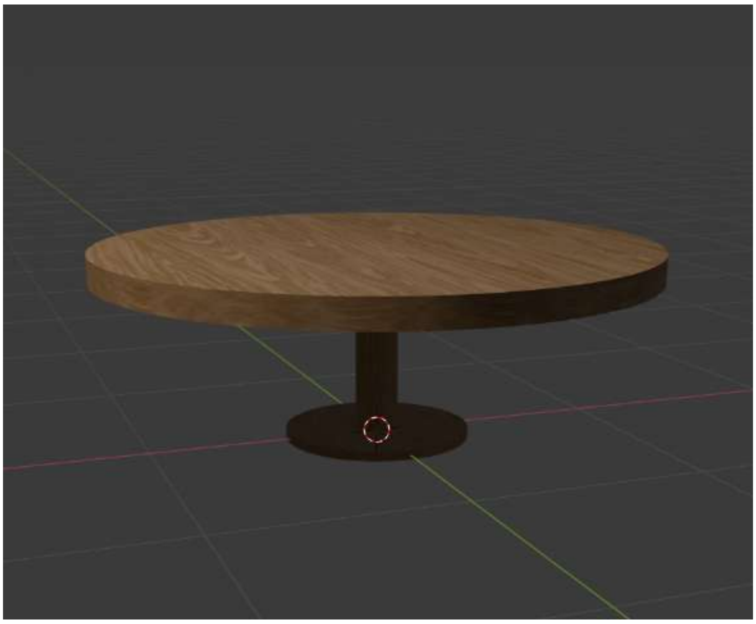
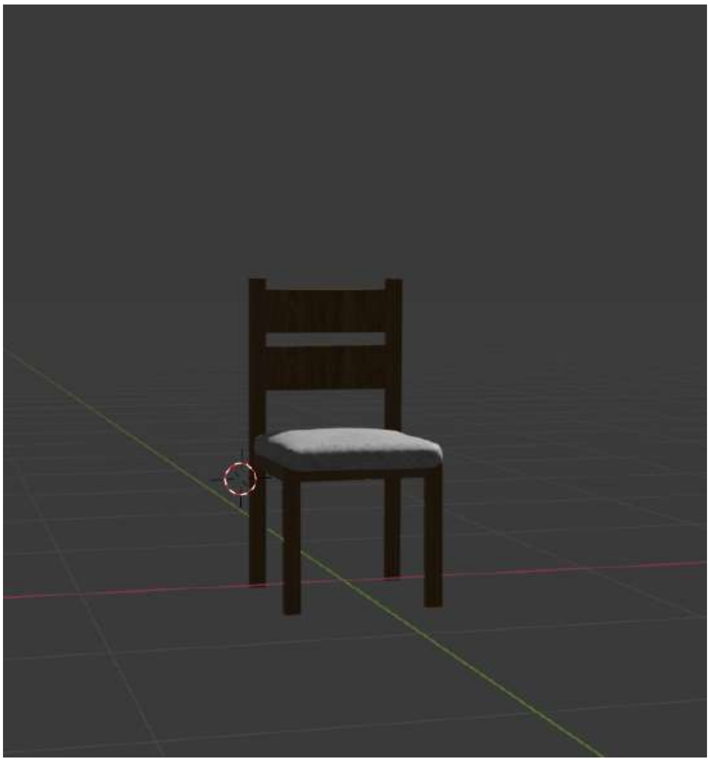


Table Blender 2 (personal file)

The chair was made with cubes in Blender and the seat was made with a fabric texture from Poly Haven (2025c).



Chair Blender 1 (personal file)

11.4.2 ChatGPT assets

The images of the external environment were created with the help of artificial intelligence. The GPT chat. The prompt was that the environment should be inspired by the world of Pandora from Avatar. In which the user would be inside a living room, floating in a world similar to Pandora. For the evening, the prompt was just Galaxia. The ChatGPT images are copyright free (OpenAI, 2025).

Pandora World 1 (OpenAI, 2025)

Pandora World 2 (OpenAI, 2025)

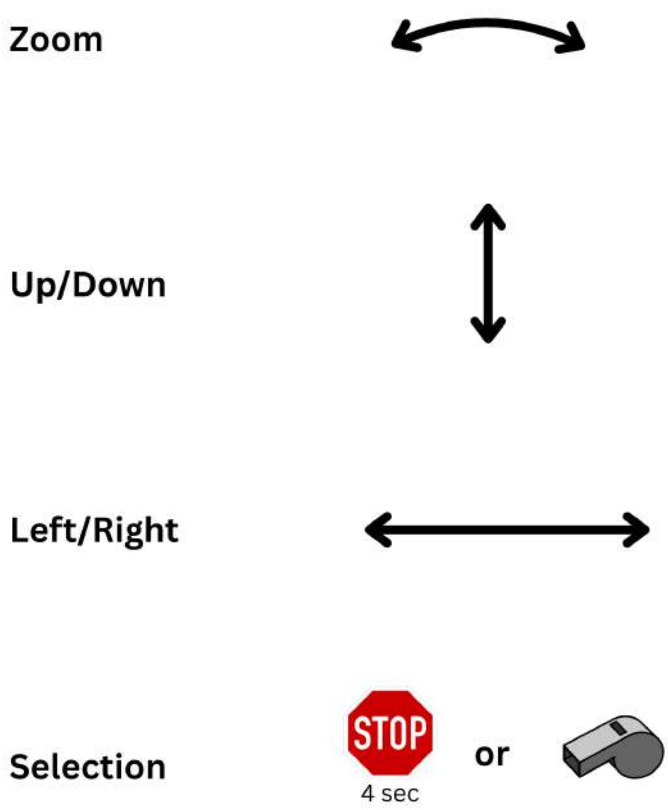
Galaxy (OpenAI, 2025)

11.4.3 Sound

The ambient and selection feedback sound was taken from the YouTube Audio Library (YouTube, 2025a & 2025b).

11.4.4 Cube and banner

The cube was created within Unity, and Canva (2025) images were placed on its faces with icons that indicate responsiveness when an activity is on or off, besides that the instruction image was also created with Canva.



Instruction Banner (personal file)

11.5 Source Code Repository

All source code, assets, scripts, and execution instructions are available in the following public repository:

https://github.com/Kethella/NavHead-VR

The repository includes:

- Source code written in C# (Unity scripts)
- Unity scene files
- 3D assets modeled in Blender
- A usage manual and setup instructions in the README.md file

The project was developed using Unity version 6000.0.24f1 and is compatible with the Meta Quest 3 headset, using OpenXR as the XR runtime.