Master thesis

Exploring the Factors Affecting Virtual Reality Technology Adoption: A Study on User Attitudes and Simulator Sickness in Virtual Reality Gaming.

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Abstract

Purposes: Virtual Reality (VR) exposure, which can induce simulator sickness, has long been acknowledged for its detrimental effects on users of VR technology. Despite the prevalent focus on promoting the immersive and captivating aspects of VR experiences, the industry has witnessed slower-than-anticipated growth, indicating a hesitancy among individuals to adopt this technology. While VR applications strive to deliver high-quality and captivating experiences, can these immersive encounters overcome users' aversion to the associated discomfort? This study also seeks to explore the gap in the existing literature concerning the association between simulator sickness and individuals' attitudes toward VR, as well as their willingness to adopt this technology.

Methods: A within-subject laboratory study was conducted to investigate this phenomenon, involving a sample of 47 participants. The study aimed to examine the impact of being exposed to the virtual environment on participants' attitudes toward VR and their willingness to adopt this technology, taking into account their pre-existing attitudes toward technology, as measured by technophilia and technophobia. During the study, participants engaged in playing three popular VR games.

Results: Our study revealed that participants' attitudes toward VR significantly predicted their willingness to adopt VR technology. However, no significant correlation was found between VR users' perceived simulator sickness and their attitudes toward VR. Nonetheless, the intensity of virtual motion during VR exposure affected users' perceived simulator sickness. Interestingly, simulator sickness is not mediated by the relationship between the two psychological dispositions of prior attitudes toward technology, presented as technophilia/technophobia and attitudes toward VR. However, both technophilia and technophobia demonstrated predictive power in relation to simulator sickness.

Conclusion: Our study highlights the significance of prioritizing individuals' attitudes to enhance their willingness to adopt VR technology. Furthermore, the adoption of trial experiences and the application of human-centered design principles in VR experience design emerge as effective strategies to positively influence individuals' readiness to adopt this technology. Moving forward, further exploration of the intricate relationship between prior attitudes and perceived simulator sickness remains a valuable avenue for future research.

1. Introduction

Virtual Reality (VR) technology has emerged as one of the most promising advancements in the 21st century (Gandhi & Patel, 2018), offering a wide array of applications across various fields (Beck et al., 2019; Freina & Ott, 2015; Greenleaf, 2016; Guttentag, 2010; Kavanagh et al., 2017; Paro et al., 2022; Pillai & Mathew, 2019; Powell, 2017; Riva, 2002). From clinical healthcare to education and entertainment, VR's immersive experiences have captured the interest of users worldwide. Particularly, the VR gaming industry stands out as a rapidly growing sector (Alsop, 2022). However, despite extensive promotion and investment, the adoption rate of this groundbreaking technology, which is inherently and intricately linked to an individual's willingness to adopt, faces barriers that impede its widespread acceptance. Among these obstacles is the phenomenon of simulator sickness, a negative effect experienced by users during VR exposure (Regan & Price, 1994; Regan, 1995; Riva, 1997; Sharples et al., 2008). Moreover, there exists a notable gap in our understanding of how individuals' attitudes toward VR contribute to this barrier (Suh & Prophet, 2018). This study aims to explore the impact of simulator sickness and attitudes towards VR on the willingness to adopt VR in the area of gaming, shedding light on essential aspects for a comprehensive understanding of VR technology's adoption dynamics.

The barrier hindering the widespread adoption of VR technology can be understood through the lens of willingness to adopt, which refers to users' willingness to invest and purchase a VR headset, a prerequisite to becoming active users of the technology. Before the outbreak of COVID-19, the sales of VR headsets experienced a dramatic surge, painting a promising picture of the technology's development (Canalys, 2017; Ericsson, 2017). However, after the peak outbreak of COVID-19, the data as of October 2022 indicated a slowdown. At that point, the market showed an estimated 74 million users and a market size of 12 billion dollars (Alsop, 2022). Although projections (Alsop, 2022; BusinessWire, 2020; Jun, 2021) suggest the market will nearly double in value by 2025, reaching $22 billion, this estimation is considerably less than the ambitious figures predicted in previous years, such as 109 billion by 2026 (in 2021) and a staggering 1,274.4 billion by 2030, projected in 2020. This slower-than-anticipated growth rate raises questions about the factors impeding a more rapid adoption of VR technology.

Adding to the uncertainty, leading companies in the VR industry have yet to disclose any official data on the quantity of VR headsets sold, further contributing to the notion that the industry remains in its infancy. Felix Richter, a data journalist from the German data and statistics firm Statista, echoes this sentiment (Richter, 2022). Moreover, Statista's research on the American market reveals that half of VR users do not personally own VR headsets and are classified as non-active users (Alsop, 2022). These individuals either share headsets with others or only engage in VR experiences sporadically. This data from 2017 to 2022, with predictions for 2023, suggests that a considerable portion of the population has displayed a low willingness to adopt VR technology, presenting a significant challenge to its broader integration into mainstream society.

In examining the willingness to adopt VR, a key factor to consider is individuals' attitudes toward VR technology. Attitudes play a crucial role in shaping people's intentions and behaviors (Ajzen, 1991), and they have been identified as significant predictors of technology adoption (Marangunić & Granić, 2015). In the context of VR, attitudes towards the technology may be influenced by the experience of simulator sickness, which is a negative side effect of VR exposure (Sagnier et al., 2020). When users are exposed to virtual environments that induce discomfort or unease, they may develop negative attitudes towards VR as a way to cope with these adverse sensations. This phenomenon can be understood through the mechanisms of defense and the concept of experiential avoidance (Altwaijri et al., 2022; Cramer, 2015; Hayes et al., 1996; Hayes-Skelton & Eustis, 2020). Individuals may subconsciously defend themselves against the aversive experiences of simulator sickness by adopting negative attitudes toward VR. Moreover, experiential avoidance, which refers to the tendency to avoid or escape from distressing experiences, may lead individuals to distance themselves from VR due to the discomfort it may induce.

VR users' perceived simulator sickness is a well-documented phenomenon that occurs during and after exposure to virtual environments. Virtually all studies on VR experiences acknowledge the presence of simulator sickness to some extent (Dużmańska et al., 2018; Grassini et al., 2021; Martirosov et al., 2022; Wang et al., 2022), and it is a key factor that warrants attention in the design and implementation of VR applications (Wang et al., 2022). While not all users may experience severe sickness, there are variations in the severity of simulator sickness depending on factors such as the duration of VR exposure and the intensity of virtual motions (Dużmańska et al., 2018; Lee et al., 2017). Studies consistently indicate that simulator sickness can have detrimental effects on the overall VR experience, including shortening the duration of the VR engagement, negatively correlated with the level of enjoyment, a critical aspect for gaming experiences (Wang et al., 2022), ultimately influencing individuals' attitudes towards VR technology (Hayes-Skelton & Eustis, 2020). Understanding the impact of simulator sickness on user experiences is crucial for developing VR applications that minimize discomfort and enhance users' overall satisfaction, ultimately promoting a more positive attitude towards VR and the willingness to adopt this technology.

In addition to studying the effect of simulator sickness on individuals' attitudes toward VR, the influence of prior attitudes toward technology in general, also plays a pivotal role. These attitudes can be basically categorized into two types: technophilia and technophobia. Technophilia represents a positive orientation and affinity toward technology, while technophobia refers to fear, dislike, or discomfort when using modern technology or complex technical devices (Osiceanu, 2015). These two psychological traits are believed to exert a strong influence on how individuals perceive and approach technology, including their attitudes toward VR. People who are technophiles are more likely to embrace the novel experiences provided by VR and may be more willing to overlook the discomfort caused by simulator sickness. On the other hand, individuals with high levels of technophobia might be more sensitive to the negative sensations induced by VR and may view them as additional barriers to adopting the technology.

As gaming is widely recognized as one of the fastest growing and heavily invested sectors, it is apparent that entertainment and gaming are among the primary reasons why users purchase VR technology. Despite this, there is a dearth of research on the impact of simulator sickness, a commonly experienced adverse effect of VR technology, on consumers' willingness to adopt VR for gaming purposes (Saredakis et al., 2020). Accordingly, we conducted a study using three current popular VR games to determine whether being exposed to the virtual environment with a modern VR headset still induces simulator sickness. Subsequently, we investigated how this phenomenon may influence users' attitudes toward VR and their willingness to adopt this technology. In short, we propose three research questions as follows:

RQ1: To what extent can attitudes towards VR predict the willingness to adopt VR among users who have experienced simulator sickness during VR exposure?

RQ2: How does VR exposure influence VR users' perception of simulator sickness, and how does this perceived simulator sickness relate to their attitudes toward VR?

RQ3: Is there a significant mediating effect of simulator sickness on the relationship between technophilia/technophobia and attitudes toward VR?

2. Theoretical framework

The theoretical framework delves into the fundamental concepts and constructs that underpin our study. It encompasses the conceptualization of willingness to adopt and attitudes toward Virtual Reality (VR) technology, explores the phenomenon of simulator sickness and its implications, examines the prior attitudes and psychological dispositions of technophilia and technophobia, and considers the influence of various factors on individuals' willingness to adopt VR technology. By exploring these aspects within the theoretical framework, we aim to provide a comprehensive understanding of the key elements shaping the experiences, the attitudes of individuals in the field of VR gaming and their willingness to adopt this technology.

2.1. Willingness to adopt VR

The theoretical framework for understanding the willingness to adopt Virtual Reality (VR) technology is built upon several models and theories. The Technology Acceptance Model (TAM) posits that an individual's intention to adopt technology is influenced by two primary factors: perceived usefulness and perceived ease of use (Marangunić & Granić, 2015). Perceived usefulness refers to the extent to which the individual believes that adopting VR technology will enhance their performance or provide benefits. Perceived ease of use, on the other hand, pertains to the individual's perception of how easy it is to use VR technology. In the context of VR adoption, users' attitudes towards the technology will be influenced by these perceptions, impacting their willingness to embrace it (Sagnier et al., 2020).

Another crucial aspect is the Theory of Planned Behavior (TPB), which emphasizes the significance of attitudes in shaping individuals' intentions and actions regarding a specific behavior (Ajzen, 1991), such as adopting VR technology. A positive attitude towards VR is likely to enhance the behavioral intention of adoption. Alongside attitudes, subjective norm (influenced by social pressure) and perceived behavioral control (belief in one's ability to perform the behavior) also play a role in influencing intentions. These factors collectively contribute to individuals' decision-making process when considering the adoption of VR technology.

In the context of VR technology, classical consumer theory comes into play, where price and satisfaction significantly affect individuals' willingness to adopt (Barten & Böhm, 1982). A favorable price point makes a product more accessible and attractive to potential users, and this could include the VR technology. Moreover, user satisfaction with the VR experience is a critical determinant of future adoption intentions. A positive and enjoyable experience with VR is likely to drive users' willingness to continue using and adopting the technology.

However, there are potential barriers to VR adoption, one of the most prominent being simulator sickness (Sagnier et al., 2020). VR users often experience discomfort and unease, resulting from exposure to the virtual environment. This negative effect can deter users from adopting VR technology. The mechanisms of defense and experiential avoidance might also contribute to individuals' reluctance to embrace VR fully (Cramer, 2015; Hayes-Skelton & Eustis, 2020). Understanding and addressing the impact of simulator sickness on users' attitudes and willingness to adopt VR is essential in developing strategies to promote wider adoption of this technology and overcoming potential barriers to VR adoption.

2.2. Attitudes toward VR

VR gaming stands as the fastest-growing segment in the VR industry (Alsop, 2022), offering users an unparalleled and immersive gaming experience that goes beyond traditional gaming. The virtual worlds created in VR gaming allow players to be fully engrossed in fantastical realms where they can interact with environments, characters, and objects, forging an unparalleled sense of presence and engagement (Heineman, 2016; Pallavicini et al., 2018). However, to fully engage players and foster positive attitudes towards VR gaming, several crucial factors come into play. When it comes to motives, players' expectations for entertainment are paramount, and any obstruction or shortfall in delivering a seamless experience can significantly impact their overall perception of VR gaming (Boyle et al., 2012).

One of the most significant challenges in VR gaming is the occurrence of simulator sickness (Shafer et al., 2019), a negative side effect that some users experience due to the discrepancy between virtual and physical motion cues (Saredakis et al., 2020). When individuals encounter simulator sickness during their VR gaming sessions, it hampers their ability to fully enjoy the experience, causing discomfort, unease, and even nausea. As a result, players may shorten their gaming sessions to avoid the unpleasant sensations, leading to reduced time engagement and entertainment (Wang et al., 2022). Moreover, simulator sickness can create a lasting impression of unease and reluctance to try VR gaming again in the future, hindering the broader adoption of this technology among gaming enthusiasts (Cramer, 2015; Hayes-Skelton & Eustis, 2020).

While addressing and mitigating simulator sickness is of importance in shaping attitudes towards VR, we must not overlook the significant influence of other factors that contribute to players' overall perception. Engaging gameplay, captivating narratives, and visually attractive graphics play a pivotal role in creating an immersive and enjoyable VR gaming experience (Yildirim, 2019). These elements not only heighten players' entertainment and engagement but also leave a lasting impression on their attitudes toward VR. However, it is essential to recognize that even with captivating content, players may face interruptions or obstacles that prevent them from further exploring the VR world. In such cases, the risk of forgetting or not fully experiencing the immersive content becomes a real concern (Sagnier et al., 2020), potentially affecting their overall attitudes and willingness to adopt VR technology in the future. Accordingly, we postulate the following hypotheses:

H1. Attitude toward VR is positively related to Willingness to Adopt VR

H2. Simulator sickness is negatively related to users' Attitudes toward VR.

2.3. Simulator sickness with VR exposure

In order to gain insights into simulator sickness, it is essential to delve into its precursor - motion sickness, which is widely considered to be the original form (Stoffregen et al., 2000). Motion sickness is a typical nuisance when traveling by car, ship, or airplane, which gives the passenger unpleasant feelings of nausea, pallor, cold sweating, and the worst is vomiting (Keshavarz & Hecht, 2011; Reuten et al., 2020). The sensory conflict theory (Oman, 1990; Reason, 1978) is one possible and well-known explanation for motion sickness. Basically, it explains that the difference in sensory modalities which is conflict is what causes the symptoms. The body's position and its movements are continuously conveyed to the central nervous system by the visual, vestibular, and proprioceptive organs. Motion sickness may arise when information from these channels is not aligned, or even when they are inconsistent with themselves. The theory also implies that the stronger the conflict, the more severe the symptoms.

Simulator sickness, the phenomenon experienced in the realm of virtual reality, shares significant similarities with motion sickness in terms of its equally strong and pronounced symptoms (Stoffregen et al., 2000). Studies have consistently identified a range of common effects associated with simulator sickness, including headaches, nausea or dizziness, ocular disorders, disorientation, balance disturbances, lightheadedness, and heightened stomach awareness (Bos et al., 2005; Regan & Price, 1994; Regan, 1995; Riva, 1997; Sharples et al., 2008). These manifestations serve as key indicators of the discomfort and unease individuals may encounter during and after exposure to the virtual environment.

Virtually all studies examining VR experiences acknowledge the presence of simulator sickness, as it is a common occurrence among users engaging with virtual environments (Dużmańska et al., 2018; Grassini et al., 2021; Martirosov et al., 2022; Wang et al., 2022). This connection between simulator sickness and VR exposure is widely established, as exposure to VR is a prerequisite for the occurrence of simulator sickness. Interestingly, despite this established link, it remains uncertain whether the duration of VR exposure directly correlates with the severity of perceived simulator sickness (Saredakis et al., 2020). Moreover, numerous other factors can play a significant role in both the occurrence and severity of simulator sickness during and after VR exposure, rendering it a complex and extensively researched area of investigation.

Virtual motion plays a pivotal role in inducing simulator sickness during VR exposure (Saredakis et al., 2020; Shafer et al., 2019). This phenomenon is influenced by various factors related to the user's interaction with the virtual environment. Locomotion, which refers to the method of movement within the virtual space, can significantly impact the experience. Different types of locomotion, such as smooth movement and teleportation, elicit varying degrees of simulator sickness due to the disparity between the virtual motion and the user's proprioceptive and vestibular senses. Additionally, the camera point of view and the user's body movement can also contribute to simulator sickness. For example, when the virtual camera moves rapidly or in a way that contradicts the user's physical movements, it can lead to discomfort and disorientation. Thus, carefully controlling the levels of virtual motion is essential in designing our study and understanding VR exposure in gaming.

The influence of hardware and software on the severity of simulator sickness is a popular topic in the field of VR research. Hardware-related factors such as low refresh rate and high latency can significantly impact the realism of the VR experience, leading to sensory conflicts and perceptual errors that can cause disorientation and nausea (da Silva Marinho et al., 2022; Wang et al., 2022). Motion blur, another common issue in virtual reality, can be exacerbated by both low refresh rates and display resolutions. In fact, display resolution has been identified as a key factor in the development of simulator sickness (Lewis & Griffin, 1997), with low resolution making it difficult for users to focus on objects or text, leading to eye strain and headaches, particularly when performing tasks that require excessive motion. Furthermore, software-related issues such as slow frame rates and poor optimization can contribute to the severity of simulator sickness by increasing latency and reducing overall immersion (Buker et al., 2012; Caserman et al., 2019). Understanding these factors, in order to avoid influencing the results of our simulator sickness research, we utilized the most up-to-date VR headset technology and regularly updated software in this research.

Another factor that contributes to the severity of simulator sickness is the novelty of people in using VR. Inexperienced users tend to experience more severe symptoms compared to those who have prior experience or regularly immerse themselves in the virtual environment. This is because the human brain takes time to adapt to the sensory inputs received from the VR headset and create a sense of presence or immersion. Inexperienced users often find it difficult to adjust to the new visual and vestibular cues provided by VR and are more susceptible to conflicts between the sensory modalities, which can cause simulator sickness. On the other hand, people with prior experience or regularly in the virtual environment have developed some level of habituation and adaptation, reducing the effects of simulator sickness. The more significant distinction in the susceptibility to simulator sickness between the two groups was found to be more pronounced among individuals who had prior experience playing games and also in their ability to recuperate after each VR session. This has been supported by a recent study by da Silva Marinho et al. (2022), which found that people with prior VR experience had lower levels of simulator sickness compared to first-time users. In the context of this study, although not the primary focus, the role of prior experience with VR will also be carefully considered and taken into account.

In conclusion, our study posits that VR exposure, irrespective of its duration, exerts a substantial influence on VR users' perceived simulator sickness. This phenomenon serves as the basis for the formulation of the following hypothesis:

H3. Simulator sickness increases with the increasing level of VR exposure.

2.4. Technophilia and Technophobia

According to Osiceanu (2015), different gadgets of modern technology that are occupying our existence generate psychological ambivalence regarding technology. In her article, she provides two terms for "technophilia" (attraction to technology) and "technophobia" (rejection of technology) to describe the two extreme positions in the continuum between advantages and the simultaneous dangers in the relationship between technology and human being, especially between technology and society. Yet, in the contemporary landscape of technology and its pervasive presence in daily life, we assert that technophilia and technophobia ought to be perceived as two distinctive dimensions inherent to individuals.

Technophilia refers to the individual's positive orientation toward technology, particularly new technology, and also the enthusiasm, pleasure, affection, and emotional qualities generated by the use of technology with its rewards, which are mostly related to ease of use and exciting experience. Technophilia is expressed by the easy adaption or quick adoption of social or personal routine changes influenced by technological innovations. (Barrientos-Gutierrez et al., 2019; Osiceanu, 2015; Ronit, 2011; Thrasher et al., 2016). The technophile, or the person who is attracted to or in favor of technology, can be seen to have a positive manner, enthusiastically and easily adopting new forms of technology to improve their living condition or to mitigate social challenges, while having no fear about the dangers, negative side-effects that technological development brings along toward society or the direct user. (Amichai-Hamburger, 2009).

On the other hand, technophobia refers to fear, dislike, or discomfort while using modern technology or complex technical devices, and is expressed by the technophobe (a person who avoids/rejects/or is afraid of technology, particularly new technology) in many forms. These expressions can go from physical avoidance, internal intense psychological struggle to organic symptoms such as sweating, shaking, heart palpitation, or stuttering. (Amichai-Hamburger, 2009; Osiceanu, 2015). Technophobia expressions and symptoms are mostly seen as irrational fear or anxiety. Although we cannot talk about technophobia in the same classic sense as other common phobias (such as arachnophobia, acrophobia, or trypanophobia) where people suffering from such phenomenons actively avoid being exposed to the situation or interacting with the stimuli, and technophobe does not completely avoid the source of their anxiety (Rosen et al., 1993), there are similarities in etiology and treatment that justify what is technophobia. (Osiceanu, 2015)

Although extant literature suggests that technophilia and technophobia are two ends of a continuum, we contend that these two constructs should be regarded as two distinct dimensions. Martínez-Córcoles et al. (2017) conducted research that demonstrates that the common questionnaires used to measure these attitudinal orientations are frequently separated and employ different items of measurement. Technophobia is often restricted to fear or discomfort, whereas technophilia is assessed through a range of dimensions, including enthusiasm, dependence, and technoreputation. Even in the very questionnaire developed and validated by Martínez-Córcoles and colleagues, these two constructs are measured using different items.

Evaluating one's prior attitudes toward technology, including VR, is essential when understanding individual attitudes toward VR. Technophiles who are enthusiastic about technology are more likely to embrace the novel experiences provided by VR and may be more willing to overlook the discomfort caused by simulator sickness. On the other hand, individuals with high levels of technophobia might be more sensitive to the negative sensations induced by VR and may view them as additional barriers to adopting the technology. Therefore, based on these considerations, we formulate two hypotheses for prior attitudes toward VR as follows:

H4: The relationship between Technophilia and Attitude toward VR is mediated by the individual's perceived simulator sickness

H5: The relationship between Technophobia and Attitude toward VR is mediated by the individual's perceived simulator sickness

2.5. Control variables

2.5.1. User characteristics factors

Lewis and Griffin (1997) identified several factors that can potentially influence an individual's vulnerability to adverse effects associated with VR usage including age, prior experience, gender, and physical fitness. Age has been studied and found to significantly impact an individual's susceptibility to motion-induced motion sickness (Reason & Brand, 1975). An average individual's susceptibility to motion sickness is greatest between the age of 2 to 12 years old. As individuals transition into adulthood to 21 years old, there is a gradual reduction in susceptibility, although a modest decline persists across the lifespan. However, it is also noticed that older individuals rather perceive more motion sickness, especially simulator sickness with VR (Classen et al., 2011). This is due to the problems with age-related changes in sensory perception and vestibular functioning, thus, influencing simulator sickness as individuals' ability to adapt to the conflict in sensory inputs is reduced.

Gender differences have also been observed, with some studies suggesting that females may be more susceptible to motion sickness and simulator sickness in VR compared to males (Classen et al., 2011; Lawson et al., 2004). However, recent research findings have brought into question the significant impacts of gender on simulator sickness (Saredakis et al., 2020). Physical fitness levels can also impact VR experiences, as individuals with better physical fitness may have improved proprioception and balance, leading to reduced susceptibility to motion-induced discomfort (Basu et al., 2016).

2.5.2. Availability and the surrounding usage

According to the theory of planned behavior (Ajzen, 1991), the willingness to adopt a VR headset can be predicted not only by the attitude toward VR technology but also by the subjective norm and perceived behavioral control. In this study, we examine the subjective norms as surrounding VR usage, seeking to understand whether individuals are more likely to adopt VR technology if they are surrounded by others who already own VR headsets. Additionally, we investigate perceived behavioral control, presented as availability, to determine if easier finding and to purchasing VR headsets leads to a higher willingness to adopt VR technology. By exploring these factors, we aim to gain a comprehensive understanding of the influences on individuals' willingness to adopt VR.

2.5.3. Price agreement

The classical consumer theory (Barten & Böhm, 1982) shows that customers are restricted by their budget to maximize their preferences. Price has always been a vital consideration for customers in purchasing a product. A price is also a tool for businesses to position their product or service in the market and to aim for a specific target customer group.

Generally, the lower the price compared to the potential average customer's budget, the higher the chance a person will decide to adopt VR technology.

2.6. Conceptual framework

The conceptual framework (Figure 1) guiding this study establishes a direct sequence of relationships: VR exposure impacts perceived simulator sickness, which in turn relates to attitudes toward VR. These attitudes are then anticipated to predict individuals' willingness to adopt VR. Moreover, the framework also hypothesizes that the connections between technophilia/technophobia and attitudes toward VR are mediated by perceived simulator sickness.

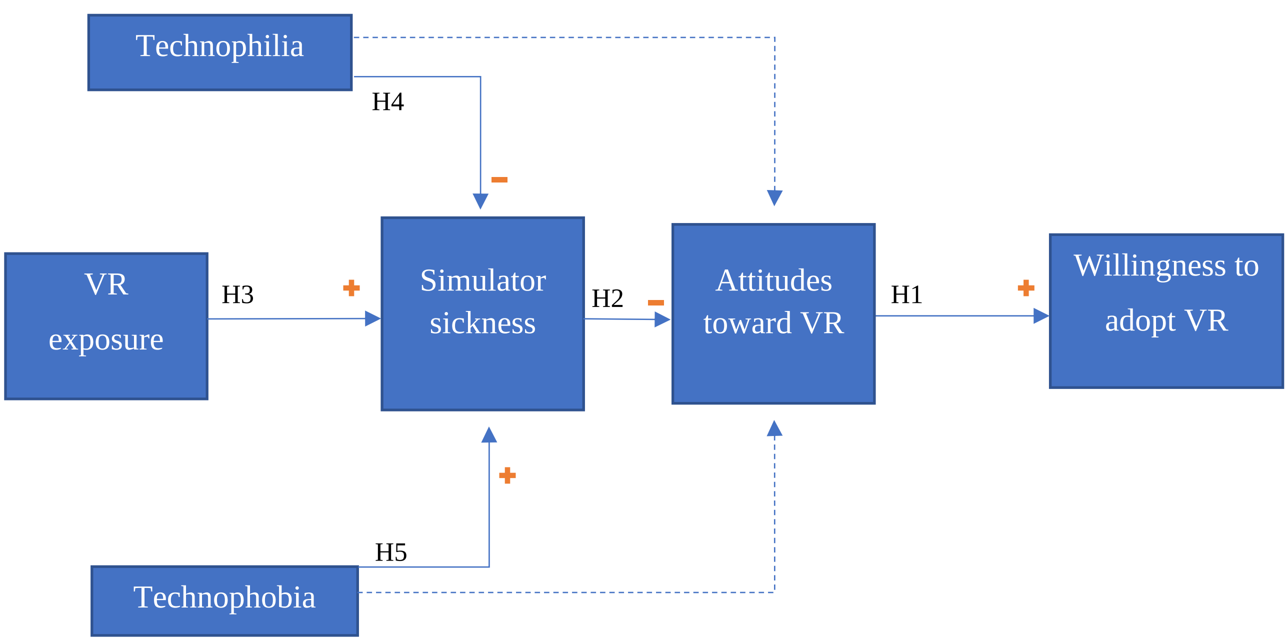

Figure 1: Conceptual framework

3. Methods

3.1. Design

This study employs a laboratory, within-subject study design to investigate the impact of Virtual reality (VR) exposure on participants' willingness to adopt VR technology. Specifically, three VR games were utilized to explore the relationship between perceived simulator sickness from VR exposure and the willingness to adopt VR. Each session lasted around 50 minutes. Participants played three games in the order determined by the pre-test, gradually increasing the level of virtual motion to better understand the relationship between VR exposure and perceived simulator sickness. It was expected that higher levels of perceived simulator sickness were associated with a lower willingness to adopt VR through lower participants' attitudes toward VR. Additionally, the study aimed to delve into the dimensions of technophilia and technophobia, positing that higher scores on technophilia correspond to a more positive attitude toward VR, while higher technophobia scores link to a decreased attitude toward VR. Participants were asked to complete a self-report closed-ended questions survey during the study for the data collection.

3.2. Participants

A total of 47 participants were recruited from the University of Twente's students and staff base ($n_{female} = 25$, $M_{age} = 23.19$, $SD_{age} = 3.89$), through the online university's research recruitment system and directed invitations. The sampling method employed for this study, therefore, was convenience sampling. As for the intention to include participants beyond university students to create a more generalized sample, 9 individuals were recruited.

All participants met the condition of having not bought a VR headset themselves for joining this study. More than half of the participants (n = 24) reported having never played games in a virtual environment before. Among the participants with prior experience with VR gaming, they stated to only play games in VR occasionally or by joining other students' VR projects or experiments. Inexperienced first-time VR players were instructed to go through an acclimatization introduction, which took 3 to 5 minutes to became familiar with being in the virtual environment.

3.3. Laboratory facility

3.3.1. Laboratory environment

The study was conducted in a well-equipped university laboratory room, spanning an area of 3x3 meters. The lab provided ample space to ensure participant safety during the VR gaming sessions, accommodating the necessary equipment while maintaining a clear, unobstructed playing area. The setup comprised a table, two chairs, and a computer, enabling the researcher to readily assist participants if needed while leaving sufficient room for engaging in the VR games. Importantly, the playing area was devoid of any hazardous objects, ensuring participants a safe and secure environment throughout the study.

Figure 2: The settings of the laboratory

3.3.2. VR headset used

The VR headset employed in this study was the Oculus Quest 2, a contemporary and technologically advanced device within the current market. The headset utilized the Qualcomm Snapdragon XR2 platform and 6GB of RAM, with a resolution of 1832 x 1920 per eye. The option of connecting the headset to a computer via cable enabled participants to engage with games that required stronger hardware or addressed graphical issues.

The decision to employ the most advanced VR headset in this study was driven by the objective of striking a balance between ethical considerations and maintaining a substantial effect size for the testing variable. Ensuring participants' comfort and safety during the intervention study was of utmost importance, and the use of modern VR headsets allows us to mitigate and not aggravate any potential negative impacts from hardware or software issues. Therefore, the implementation of the Oculus Quest 2 VR headset provided a suitable platform for investigating the impact of virtual reality on the participants' perceptions and experiences.

3.3.3. PC used

The VR headset used in the study was connected via cable to an Acer Nitro 5 gaming laptop. This laptop, equipped with an Intel Core i5 10th generation processor, 16GB of RAM, and an NVIDIA GeForce GTX 1650 Ti video card, served as the main system for running the VR games. By connecting the VR headset to the laptop, researchers had the ability to easily observe inside the virtual environment and provide guidance or instructions to the participants when needed, or assist if there was a technical problem.

3.4. Pre-testing and descriptions of the games

3.4.1. Pre-testing procedure

The pre-test session was conducted with a group of university students (n = 8; M_{age} = 20.38; SD_{age} = 1.19) with the goal of objectively validating the varying effect of virtual motion of the games used in the study and how they were experienced. Unlike the official study, the pre-test requires participants to play 4 VR games (Beat Saber, Gorilla Tag, VR Chat, and Echo VR), from which 3 games were selected (excluding Echo VR). Participants were clearly informed about the pre-test process, the purpose of the main study, the right to withdraw and the risks they may face. The pre-test started only when the participants understood and agreed to the above.

Participants were given time to fully experience Oculus First Contact (acclimatization introduction) as a familiarization to be immersed in the virtual environment if they chose to. The MISC score, used to indicate perceived simulator sickness (discussed in 3.5.1., see Appendix D), was evaluated for the first time at this point for manipulation check and once after each game was finished. All pre-testing participants reported no problems, with the exception of one who experienced slight discomfort due to it being their first experience with virtual reality. Notably, none of the participants dropped out of the study midway, and none of them experienced severe symptoms of nausea, which surpassed the limit for continuing.

Participants in the pre-test were asked to provide ratings on a 10-point scale regarding their perception of the game's virtual motion. Each participant played the games in a randomized order to reduce the order effects. Given the lack of clear and validated indicators for evaluating the virtual motion of the games, participants were allowed to modify their ratings of each game at any time based on their personal perceptions. This allowed for a more flexible and accurate assessment of the virtual motion of the games.

Finally, three games with player ratings of incremental virtual motion were selected for use in the main study. One game in the pre-test with a high rating for the virtual motion was excluded with the reason that getting used to the game's missions, controls, and requirements took too long for a study.

3.4.2. Chosen games for the study

The selection of games for this study was based on popularity indicators such as the number of players online, sales/downloads, and ratings on reputable platforms like Steam and Oculus Store. The choices were constrained by geographical accessibility and the research team's capacity to procure the games for the study.

Acclimatization introduction: Oculus First Contact

First Contact was a designed VR experience built as the official acclimatization introduction to introduce VR users of Oculus to the virtual environment. The experience takes place in a small room where users interact with a robot and a floppy disk player, which provide futuristic toys, allowing players to intuitively learn how to make use of the controllers and navigate around.

Game 1: Beat Saber

Beat Saber (Beat Games, n.d.) gained popularity in the VR gaming community quickly after it was introduced to the public as a skill-based game. The game allows players to enjoy music in a different way by using controllers to slash through blocks and dodge obstacles according to the rhythm of their favorite songs. Although often classified as fitness games, players of the pre-test session felt that the game had a relatively low level of virtual motion. ($n_{pre-test} = 8$; $M = 1.88$; $SD = 0.86$). In the pre-test, participants were free to choose to play among the available songs, as well as freely choose the difficulty of the song. They can also stop the song early or replay it as they wish, creating the most comfortable and confident playing experience.

Game 2: Gorilla tag

Another popular and widely played game is Gorilla Tag (Gorilla Tag, n.d.). With a fairly simple, traditional gameplay based on a chase game, the game invites players to perform running, jumping, and swinging just by-hand movements at a fairly high speed based on the player's ability. Despite the different game modes, participants were only required to individually enter the default world, move, and play according to their preferences. In-game communication was restricted as participants found themselves in a private session to ensure participant privacy and prevent any potential distractions that could affect the participants' overall playing experience. Participants said that the feeling of free fall and turning their heads to look in many directions in the game were factors that easily lead to feelings of discomfort and fatigue. Evaluations of participants in the pre-test session showed that Gorilla Tag could be classified as a game with a medium level of virtual motion. ($n_{pre\text{-}test} = 8$; $M = 3.63$; $SD = 0.92$)

Game 3: VR Chat

Unlike the previous two games, VR Chat (VR Chat, n.d.) aims to build a virtual reality environment that integrates many different experiences. In VR Chat, players are able to play minigames, freely explore different worlds such as nature, art museums, or watch movies together in a large cinema. Within the scope of this study, participants were asked to enter a world called "Tub tub world" - one of the featured worlds. Here, players can both enjoy the natural scenery combined with playing mini-golf. Participants reported that, although they were not asked to perform difficult tasks, the perception of virtual motion was quite high with VR Chat ($n_{pre\text{-}test} = 8$; $M = 6$; $SD = 1.51$). This comes from moving in the game at unusual speeds, head movements to look around, sudden changes in brightness, and differences in resolution display. In the pre-test, even though they were only in VR Chat for a short time, most of the participants said they felt unwell, leading to high ratings for MISC afterward.

Game 4: Echo VR (excluded from the main study)

Echo VR (Echo VR, n.d.) is a virtual reality game featured on the Oculus Store. The game is set in a futuristic zero-gravity environment where players assume the role of robots and engage in competitive sports, such as disc-based battles and moving through space using their hands and body movements. In the pre-test, participants reported a high virtual motion score ($n_{pre\text{-}test} = 8$; $M = 6.75$; $SD = 1.04$), indicating a high level of perceived simulator sickness during gameplay. Due to the observed complexities and lengthy learning curve of the game, it was decided to exclude Echo VR from the main study to maintain a streamlined and consistent experience for participants, as they required substantial assistance and time to understand and navigate the game effectively.

3.5. Measures

3.5.1. Willingness to adopt VR

The scale employed to measure participants' willingness to adopt VR technology was a single-item 7-point scale. Participants were asked to indicate their agreement with the statement, "I would love to buy a VR headset." Responses were rated on a scale of 1 to 7, where 1 represented "Strongly Disagree" and 7 represented "Strongly Agree." This single item was administered twice: once before the study exposure and once after. The final value for each participant was calculated by subtracting the pre-exposure score from the post-exposure score, revealing the change in their willingness to adopt VR ($n = 46$; $M = 0.63$; $SD = 1.82$).

3.5.2. Attitudes toward VR

The measurement of attitudes toward VR in this study employed a self-report approach, utilizing a 5-point Likert scale consisting of four items (Appendix C). Participants were asked to indicate their level of agreement or preference for VR-related experiences. The preference measure was administered twice: once at the beginning of the study ($n_{items} = 4$, *Cronbach's* α = .79) and again at the end, following the completion of the three VR games ($n_{items} = 4$, *Cronbach's* α = .85). The obtained Cronbach's alpha values for both measurements were high, indicating relatively high internal consistency and intercorrelation among the items.

3.5.3. Simulator sickness

The measurement of simulator sickness symptoms, known to diminish the immersive and enjoyable nature of VR gaming experiences, has garnered significant attention in scholarly research (Reuten et al., 2020). While objective measures such as observing physical signs like pallor, heart rate variability, and hormonal changes have been explored, they exhibit limitations in accurately capturing the severity of these symptoms. Consequently, this study adopts a self-reported questionnaire approach. Specifically, the MIsery SCale (Appendix D – Bos et al., 2005) has been incorporated, consisting of a single item that prompts participants to indicate their current level of distress on a continuum ranging from 0 (No symptoms) to 10 (Vomiting). It is worth noting that participants were actively reminded that they could stop the study if they wanted to, but none of the participants reached the extreme point of vomiting or stop the study. The MISC scale was administered four times throughout the study: at the outset and after each game session.

3.5.4. Technophilia and technophobia

The previous section has posited that technophilia and technophobia are not polar opposites on a continuum but rather represent distinct dimensions that require separate scales for measurement. Consequently, it was anticipated that individuals may score high on both the technophilia and technophobia scales, as well as low on both scales. The measurement of technophilia was derived from the scale developed by Barrientos-Gutierrez et al. (2019), while the measurement of technophobia drew from the scale in the study by Heinssen et al. (1987). Both scales were further adapted to the work of Martínez-Córcoles et al. (2017), where each item would be indicated with the participant's agreement to a statement. The questionnaire for technophilia and technophobia consisted of 16 items in total (Appendix A), with eight items dedicated to each construct, and was randomized for better internal consistency reliability and reduce the order effect. Participants expressed their level of agreement with each statement using a 6-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree." An example statement for technophilia was "I find technology to be an integral part of my daily life.", and for technophobia, it was "I am concerned about the potential loss of privacy and security in a highly technological world."

Factor analyses and reliability analyses were conducted for the original 16 items, resulting in the extraction of two factors for technophilia comprising five items ($n_{items} = 5$, *Cronbach's* α = .76), and technophobia comprising eight items ($n_{items} = 8$, *Cronbach's* α = .74) (Appendix B). Furthermore, three items were excluded from the scale. These items exhibited low factor loadings (lower than 0.40) on both components. However, item number 6 was an exception, as it demonstrated a higher than 0.40 factor loading (at 0.408) on the technophilia component but adversely affected the overall Cronbach's alpha, therefore being excluded (Table 1). Both the scales measuring technophilia and technophobia demonstrated satisfactory levels of internal consistency reliability, which surpass the conventional threshold of 0.70, indicating that both scales are suitable for use in assessing individuals' levels of technophilia and technophobia.

Notably, among the full set of items, three exhibited high factor loadings on both components of technophilia and technophobia. Specifically, Item 2 within the technophilia component and Item 4 within the technophobia component demonstrated such dual high loadings. It is important to highlight that, although both items exhibited substantial loadings on both factors, one factor loading was relatively higher compared to the other, and these factor loadings remained notably high among those of other items. Furthermore, the lower factor loadings of these items merely exceeded the threshold of 0.40. Additionally, Item 13 displayed almost equivalent factor loadings for both components, though it was ultimately included within the technophobia component due to its slightly higher factor loading and its original conceptual alignment with technophobia.

Table 1

Results from Factor Analyses of the Mixed Questionnaire of Technophilia and Technophobia [a]

	Component	
	1	2
Factor 1: Technophilia		
1. I find technology to be an integral part of my daily life.	.796	
2. I enjoy exploring and adopting the latest technological devices and gadgets.	.611	-.404
7. I enjoy using new equipment or technology.	.703	
8. I think it is necessary to teach young students about modern technology.	.625	
15. I feel uncomfortable when I use new equipment or technology. (R)	.771	
Factor 2: Technophobia		
3. I consider myself an early adopter of new technologies. (R)		.655
4. I feel a sense of satisfaction and fulfillment when using cutting-edge technology. (R)	-.477	.546
5. I am excited about new equipment or technology. (R)		.576
11. I worry about the negative impact of technology on society.		.574
12. I find it challenging to keep up with the rapid changes in technology.		.450
13. I feel overwhelmed by the complexity of modern technology.	-,501	,512
14. I am concerned about the potential loss of privacy and security in a highly technological world.		.726
16. I love being away from screens for days.		.644

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Note. N = 47. Factor loadings above .40 are presented. Reversed-scored items are denoted with (R)

3.5.5. Control variables

The control variables in this study were assessed through various scales. To gauge participants' fitness habits, a single item was utilized, prompting participants to respond to the question, "How often do you work out or go to the gym?" Responses ranged from 1 = "I don't work out or go to the gym" to 4 = "I work out or go to the gym daily but skip occasionally".

Prior experience with VR gaming was assessed with a simple binary response: participants were asked, “Have you ever played games in Virtual Reality before?”, with the options "Yes" or "No." The scale measuring surrounding VR usage aimed to gauge participants' perceptions of the prevalence of VR headset ownership among those close to them. Using a 7-point scale, participants indicated their awareness of VR headset ownership in their circle, with responses ranging from 1 = "None at all" to 7 = "A great deal” to the question “To your knowledge, how many people close to you (e.g. friends, family) own a VR headset?”.

To capture participants' perceptions of the availability of VR headsets, a single item was used, asking participants, "For availability, how easy is it for you to find and buy a VR headset when you want to?" Responses were recorded on a 7-point scale, ranging from 1 = "Extremely difficult" to 7 = "Extremely easy". Lastly, participants' agreement with the price of the Meta Oculus Quest 2 VR headset was assessed using a single-item scale. Participants were asked to express their opinion on “Currently, the official price of a Meta Oculus Quest 2 VR headset is

€449.99. Do you think this is a good price?", with response options ranging from 1 = "Strongly Disagree" to 7 = "Strongly Agree".

3.6. Procedure

Participants received detailed information about the study's procedure, ethical approval, and potential symptoms and sensations associated with the experience (such as headaches, nausea, dizziness, ocular disorders, disorientation, balance disturbances, lightheadedness, and stomach awareness). They were given time to decide whether to participate in the study. Those who chose to proceed will fill in a self-report survey to provide their age, gender, fitness habits, and prior experiences with VR gaming. Next, the participants responded to the questionnaire on technophilia and technophobia (Appendix A).

Before participants engaged in playing the three VR games with increments in virtual motions (selected based on a pre-test), they received instructions on how to use the VR headset and could choose to familiarize themselves with the virtual environment in an acclimatization introduction (which took three to five minutes). As part of the survey, participants were asked to indicate their willingness to adopt VR, to provide a rating on the MIsery SCale (MISC - Appendix D) to reflect their current malaise or discomfort, and to indicate their attitudes toward VR through a set of questions included in Appendix C.

The study involved playing three short, interactive video games, each lasting 10 minutes. Participants had the option to withdraw from the study at any time. After each game, participants updated any changes on the MISC scale. Resting time will be provided, and participants will have access to drinking water and candy for sugar if desired. The next game will only commence when the participant feels ready, as this approach aims to minimize the potential effects of prolonged exposure to simulator sickness.

After all the games were completed, participants were asked to express how was the virtual reality experience with a qualitative comment, again indicating their attitudes toward VR, their current point on the MISC, and any revisions to their willingness to adopt a VR headset. Participants were encouraged to express the reasons behind their willingness or reluctance to adopt VR, thereby providing valuable context and depth to their responses and adding valuable insights next to quantitative works.

As final questions, to evaluate the control variables, participants were asked how many people in their immediate circle were VR headset owners (surrounding VR usage), how simple it was for them to buy a VR headset (Availability), and what price they believe is fair for this technology *(*Price agreement).

4. Results

4.1. Relationship between Attitude toward VR and Willingness to adopt VR

Our first hypothesis (H1) postulated a positive relationship between individuals' attitudes toward VR and their willingness to adopt the technology. Using correlation analysis, as indicated in Table 4, showed a significant correlation between attitude toward VR and willingness to adopt VR (*Pearson's* $r = .62$, $p < .001$). Utilizing multiple-level regression models (see Table 2) further confirmed this significant correlation across all steps, when adding more variables to the model. Therefore, H1 was supported, indicating a strong connection between attitudes toward VR and willingness to adopt VR.

It was worth noting that, using a paired-sample t-test, the result indicated a significant shift in participants' willingness to adopt VR ($t_{(46)} = 2.55$, $p = .014$). Specifically, the results revealed a notable increase in participants' willingness to adopt VR before ($n = 47$; $M = 4.47$; $SD = 1.43$) and after the study ($n = 47$; $M = 5.15$; $SD = 1.53$), indicating that their inclination to purchase a VR headset was enhanced after the gaming experience.

Table 2.

Hierarchical Regression Results for Willingness to Adopt VR

Variable	Step 1	Step 2	Step 3
	Standardized Coefficients β	Standardized Coefficients β	Standardized Coefficients β
Constant			
Attitudes toward VR	$.62^{***}$	$.64^{***}$	$.50^{**}$
Simulator sickness (MISC)	-	.10	.10
Technophilia	-	.22	.13
Technophobia	-	-.03	-.03
Age	-	-	-.06
Gender	-	-	.03
Fitness habit	-	-	.17
Prior experience with VR	-	-	.13
Surrounding VR usage	-	-	.12
Availability	-	-	.10
Price agreement	-	-	.25
R^2	0.39	0.43	0.53
ΔR^2	0.39^{***}	0.04	0.10

Note. MISC = rated point by the participants for their perceived simulator sickness; Availability = the availability of VR to buy by the participants.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

4.2. Relationship between Simulator sickness and Attitudes toward VR

Our second hypothesis (H2) postulated a negative relationship between individuals' perceived simulator sickness and their attitude toward VR. Our findings revealed a significant linear correlation between simulator sickness and attitude toward VR (*Pearson's* $r = -.29$, $p = .03$), as presented in Table 4. However, our multiple-level regression model in Table 3 indicated that simulator sickness was not significantly associated with attitude toward VR. The significance levels for both step 1 ($\beta = -.29$; $t = -1.99$; $p = .05$) and step 2 ($\beta = -.31$; $t = -1.90$; $p = .07$) were close to the conventional threshold. Notably, the model's R^2, which measures the proportion of the variance in the dependent variable explained by the independent variables, was relatively low. This suggests that the variations in attitude toward VR were only moderately explained by the variations in simulator sickness. In conclusion, our analysis did not fully support H2, as there was no statistically significant relationship between simulator sickness and attitude toward VR in our model.

However, with the inclusion of control variables in the predictive model for attitude toward VR, there was a significant increase in the model's R^2 value, signifying a more comprehensive explanation of the variance in attitude toward VR. Within this expanded model, age emerged as a significant predictor, displaying a substantial standardized coefficient in relation to attitude toward VR.

Table 3.

Hierarchical Regression Results for Attitude toward VR

Variable	Step 1	Step 2	Step 3
	Standardized Coefficients *β*	Standardized Coefficients *β*	Standardized Coefficients *β*
Constant			
Simulator sickness (MISC)	-.29	-.31	-.30
Technophilia	-	-.10	-.16
Technophobia	-	-.04	.11
Age	-	-	-.43**
Gender	-	-	.10
Fitness habit	-	-	.05
Prior experience with VR	-	-	.19
Surrounding VR usage	-	-	-.01
Availability	-	-	.24
Price agreement	-	-	.19
R^2	0.08	0.09	0.40
ΔR^2	0.08	0.01	0.32*

Note. MISC = rated point by the participants for their perceived simulator sickness

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 4.

Descriptive Statistics and Correlations for Study Variables

	Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
1.	Willingness to adopt VR	0.63	1.82	-											
2.	Attitudes toward VR	0.09	0.67	$.62^{***}$	-										
3.	Simulator sickness - MISC	3.00	2.62	-.19	$-.29^{*}$	-									
4.	Technophilia	4.76	0.80	.22	.04	$-.41^{**}$	-								
5.	Technophobia	3.36	0.78	-.15	-.11	$.38^{**}$	$-.37^{**}$	-							
6.	Age	23.26	3.90	$-.25^{*}$	$-.41^{**}$	.22	-.14	$.33^{*}$	-						
7.	Gender	1.52	0.50	.02	.06	.13	-.17	.23	.11	-					
8.	Fitness habit	2.09	0.89	.08	-.09	.00	.02	-.04	.09	-.15	-				
9.	Prior experience with VR	1.52	0.50	-.22	.11	.24	-.01	.10	.23	.22	-.00	-			
10.	Surrounding VR usage	1.65	0.64	.00	-.11	$-.25^{*}$	.23	.12	.19	-.05	.17	$-.25^{*}$	-		
11.	Availability	3.28	0.98	$.33^{*}$	$.26^{*}$	-.04	.18	-.15	.03	-.17	-.13	.10	.05	-	
12.	Price agreement	2.65	1.12	$.47^{***}$	$.41^{**}$	$-.26^{*}$	.18	-.15	-.20	.01	-.21	.17	-.20	$.35^{**}$	-

Note. n = 46

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

4.3. Relationship between VR exposure and Simulator sickness

To examine the increment in perceived simulator sickness after VR exposure, participants' ratings on the MISC scale were analyzed using repeated measures ANOVA with three levels ($F_{(1, 46)} = 122.39$, $p < .001$), with each value documented after each game (Fig. 3). The results firstly indicated that there was a significant difference in perceived simulator sickness between the games participants played.

However, Mauchly's test of sphericity indicated a violation of the assumption of sphericity (*Mauchly's W* = 0.75, *df* = 2, *p* = .001), suggesting that the variances of the differences between all possible pairs of conditions were not equal. In order to address this violation and adjust to controlling the risk of committing Type I errors, two corrections were applied: the Greenhouse-Geisser correction and the Huynh-Feldt correction. The p-values associated with Greenhouse-Geisser correction ($F_{(1.60, 73.41)}$ = 35.68, $p < .001$, *Greenhouse-Geisser's* ε = 0.80) and with Huynh-Feldt correction ($F_{(1.64, 75.63)}$ = 35.68, $p < .001$, *Huynh-Feldt's* ε = 0.82) were both found to be statistically significant, indicating that there were significant differences in the perceived simulator sickness after each game.

Our third hypothesis H3, which proposed an increase in simulator sickness with the increasing level of VR exposure, finds support in the results of our study. The application of repeated measures ANOVA revealed a significant difference in perceived simulator sickness among the games participants engaged with. Furthermore, we employed paired-sample t-tests to investigate specific game comparisons. The outcomes of these tests highlighted a substantial rise in an individual's perceived simulator sickness following each game experience. Specifically, the comparisons between Game 1 and Game 2 ($t_{(46)}$ = 7.34, $p < .001$) and between Game 2 and Game 3 ($t_{(46)}$ = 2.89, $p = .006$) demonstrated noteworthy increases. These findings collectively affirm our hypothesis H3, indicating that the increasing level of VR exposure indeed leads to a significant elevation in perceived simulator sickness. (also see Figure 3)

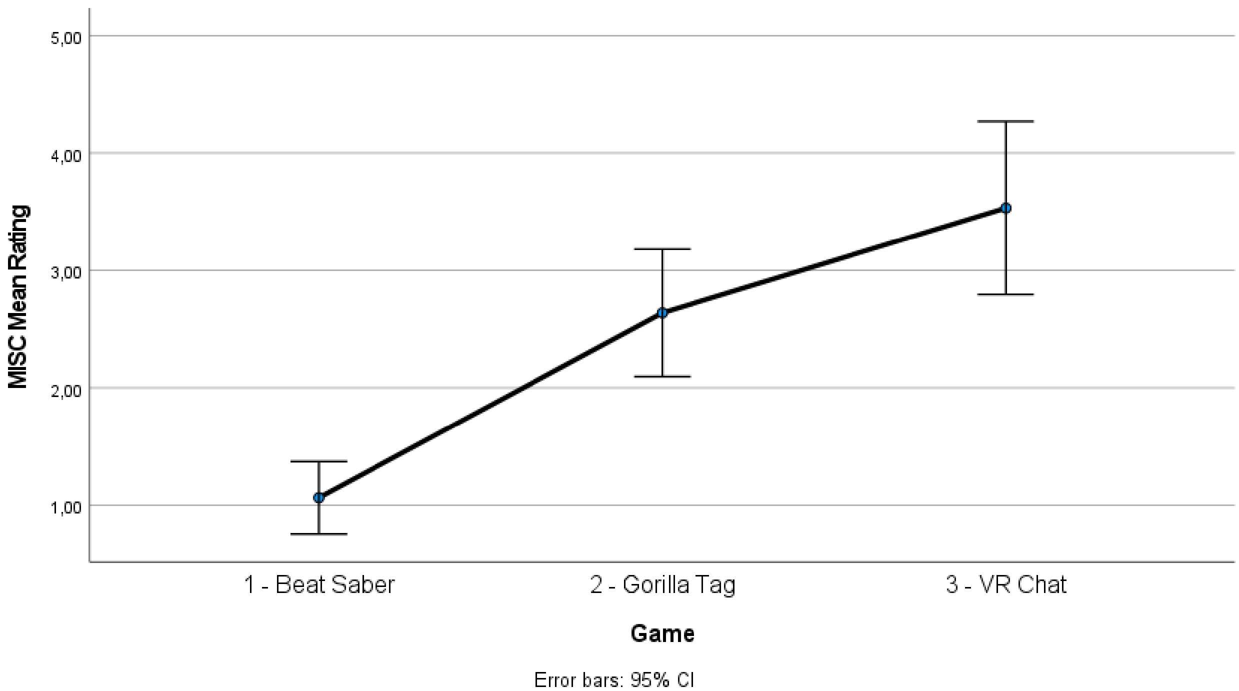

Figure 3: Repeated measures ANOVA on perceived simulator sickness of three games

4.4. Technophilia and Technophobia

To examine the mediated effect of simulator sickness on the relationship between technophilia/technophobia and attitudes toward VR, we employed Baron and Kenny's statistical mediation analysis (1986).

Our H4 posited that the relationship between Technophilia and Attitude toward VR is mediated by the individual's perceived simulator sickness. The coefficient between technophilia and the mediator MISC was found to be significantly related. However, upon investigating the relationship between technophilia and attitude toward VR, it was observed that technophilia itself was not significantly related to attitude toward VR. Moreover, the mediator variable MISC also exhibited no significant relationship with attitude toward VR. This suggests that the crucial condition for analyzing a mediation effect, which was the presence of a direct relationship between the predictor and the criterion variable, was not met. Consequently, there was no evidence to support the mediation effect of MISC on the relationship between technophilia and attitude toward VR. As a result, our H4 was not supported by the data.

Similarly, our H5 postulated that the relationship between Technophobia and Attitude toward VR is mediated by the individual's perceived simulator sickness. The relationship between technophobia and MISC was indeed found to be significant. However, similar to the results of H4, the relationship between technophobia and attitude toward VR was not significant. Given that this essential criterion for mediation analysis was not fulfilled, the proposed mediation effect of MISC on the relationship between technophobia and attitude toward VR was not supported. In conclusion, our findings did not provide evidence for the mediation effect posited in H5.

Table 5

Mediation Analysis Results

Model	*Beta* X -> M	*p*	*Beta* X -> Y	*p*	*Beta* M -> Y	*p*	*Beta* X + M -> Y	*p*
Technophilia as X	-1.36	.01	0.03	.79	-0.07	.05	-0.08	.05
Technophobia as X	1.23	.01	-0.10	.45	-0.07	.05	-0.07	.08

Note. X = independent variable, including technophilia and technophobia. M = mediator, including simulator sickness (MISC). Y = dependent variable, including attitude toward VR.

4.5. Control variables

The correlations of several control variables on the willingness to adopt VR were also examined (Table 4). Age and agreement with the price were found to correlate with the willingness to adopt VR significantly. Older individuals showed a lower willingness to adopt VR, while participants who expressed higher agreement with the price were more likely to embrace VR technology, suggesting that age-related differences and perceived value play important roles in shaping individuals' willingness to adopt VR. Other control variables, such as gender, fitness habits, prior experience with VR, and the presence of VR owners in one's social circle, did not show significant correlations in this study.

5. Discussions

The Virtual reality (VR) exposure to virtual motion and perceived simulator sickness has been recognized by its negative impact on individuals using VR, evoking uneasy feelings, reducing engagement time, and diminishing the overall entertainment experience (Shafer et al., 2019; Saredakis et al., 2020). Moreover, the market development for VR has shown slower growth than anticipated, indicating hesitancy among potential adopters. Given these circumstances, the objective of our study was to investigate the influence of VR exposure on individuals' perceived simulator sickness, and how simulator sickness related to attitude toward VR and willingness to adopt VR. Additionally, we aimed to explore the role of prior attitudes toward technology, as represented by technophilia and technophobia, and their relationships with simulator sickness and attitudes towards VR – a predictor for willingness to adopt. By addressing these objectives, we sought to shed light on the factors influencing VR adoption and deepen our understanding of the complex interplay between VR exposure, perceived simulator sickness, prior attitudes, and individuals' attitudes toward VR technology.

The strong and consistent predictive power of attitude toward VR on individuals' willingness to adopt this technology was a significant finding in our study. This predictive relationship persisted even as more variables were introduced into the complex regression models. This outcome underscores the critical role that users' attitudes and perceptions play in the context of designing VR experiences, as these factors can profoundly influence their willingness to embrace such technology. This observation emphasizes the value of the technology acceptance model (TAM - Marangunić & Granić, 2015; Sagnier et al., 2020), suggesting that individuals' cognitive attitudes about VR play a pivotal role in shaping their behavioral intentions.

Throughout the session involving the participation in three VR games, participants' perceived usefulness and ease of use of VR might enhanced, resulting in an increase in their willingness to adopt the technology as the sample contained largely inexperienced VR users. Comments from participants echoed this shift, with sentiments such as "It was quite funny and engaging to participate, which is why I see it as a good new thing to play" and "I think it's a really cool concept, it's a change to the traditional game playing methods nowadays." This implies that experiencing a new technology firsthand can indeed positively affect attitudes and, consequently, enhance willingness to adopt.

While these findings further confirm the TAM's significance, they also bring the value of the theory of planned behavior (TPB - Ajzen, 1991) into question in today's technologically evolved world. Among the TPB factors investigated—attitude, subjective norm, and perceived behavioral control—only attitude showed a robust link to behavioral intention. Subjective norm, which relates to surrounding VR usage, might have been overshadowed by the individual assessment inherent in the TAM. Perceived behavioral control, tied to the availability of VR for purchase, may not hold as much sway in the era of easy online shopping. Nonetheless, further research is warranted to delve deeper into these two factors to see if they still play important roles in behavioral intention.

The enduring and pivotal link between attitude toward VR and willingness to adopt it serves as a fundamental pillar when assessing the value of the adoption of new technologies. This underscores the necessity for technology developers to concentrate on cultivating positive user attitudes. The significance of this connection also underscores the urgency of adopting not just user-centered but human-centered design principles (Boy, 2017; Boyle et al., 2012; Kim & Lee, 2022; Sagnier et al., 2020). While the user-centered design is integral in creating products that meet users' needs and preferences, human-centered design takes it a step further by encompassing a holistic understanding of the user experience, emotions, and attitudes.

As participants' exposure to VR increased, we observed a corresponding escalation in their perceived simulator sickness. This elevation was attributed to both heightened virtual motion and exposure duration. These outcomes align with current research indicating that simulator sickness is an inherent aspect of VR use (Saredakis et al., 2020; Shafer et al., 2019), varying in severity among individuals. The findings further emphasize the importance of adopting a human-centered approach in designing VR experiences to accommodate diverse user backgrounds, preferences, and comfort levels, potentially ameliorating perceived simulator sickness. Interestingly, our findings contrast with an earlier study by Lewis and Griffin (1997), which proposed hardware limitations and low-resolution displays as contributors to simulator sickness. Our observations of simulator sickness occurrences, even with modern VR headsets, call for further inquiry, using advanced technology to determine the persistence of this phenomenon.

Remarkably, our study unveiled a lack of a significant relationship between perceived simulator sickness and attitude toward VR. While this relationship did not attain conventional significance, its proximity to the threshold warrants careful consideration. These findings suggest that despite the potential discomfort of simulator sickness, individuals sustain a positive disposition and enthusiasm for VR adoption, suggesting that perceived simulator sickness might not hinder VR adoption. Nevertheless, given the near-significant nature of this relationship and its substantial zero-order correlation, future investigations should scrutinize this link with diverse samples and alternative measures of perceived simulator sickness.

Noteworthy within our study was the substantial predictive potency of age concerning attitude toward VR, as evidenced by regression analysis. Interestingly, older participants displayed less favorable attitudes toward VR, particularly in the realm of VR gaming. This observation might stem from slower adaptation to VR experiences and potential differences in perceiving the entertainment value. Moreover, prior research by Classen and colleagues (2011) proposed a non-linear connection between age and simulator sickness, suggesting a decrease around the age of 21 followed by an increase. Given that our sample's average age hovered around 23, exploring various age groups could furnish valuable insights into the connection between perceived simulator sickness and attitude toward VR.

In addressing the research question concerning technophilia and technophobia, our analysis unveiled an absence of mediated effects involving simulator sickness on the associations between these psychological dispositions and attitudes toward VR. Nevertheless, our findings revealed intriguing dynamics between both technophilia and technophobia and individuals' perceived simulator sickness. Specifically, a high technophilia score correlated with reduced perceived simulator sickness, while a high technophobia score corresponded with heightened perceived simulator sickness. This confirms the alignment with the patterns observed in how individuals with technophilic and technophobic tendencies handle technological risks (Osiceanu, 2015). This observation brings to light an interesting paradox: the propensity to experience simulator sickness did not predict individuals' attitudes toward VR, yet their pre-existing attitudes significantly predict their susceptibility to simulator sickness. Our study establishes a novel connection between pre-existing attitudes and simulator sickness, a relationship that has not been previously highlighted (Saredakis et al., 2020; Shafer et al., 2019). This intricate interplay prompts the exploration of the intricate mechanisms underlying the relationship between simulator sickness and individuals' attitudes, warranting further investigation in future research endeavors.

5.1. Limitations

Our study was subject to several limitations that warrant consideration. Firstly, our sampling method primarily targeted university students, which may limit the generalizability of our findings. Future research should aim to extend the sample size and include a more diverse age group to obtain a more comprehensive understanding of the population's attitudes toward VR adoption. Additionally, exploring other settings beyond university campuses could provide valuable insights into how different demographics perceive and adopt VR technology.

Furthermore, our study design involved a within-subject approach, which may have its drawbacks. Employing a between-group experimental design, with a control and experimental group, would allow for a more robust examination of the relationships between simulator sickness, varying levels of virtual motion, and preferences and attitudes toward VR. This would help elucidate how different VR experiences influence users' perceptions and willingness to adopt the technology.

Another limitation was related to the selection of VR games used in the study. While we chose popular VR games, our study's scope was limited to a few specific titles. Exploring a broader range of games could yield different results and provide additional insights into the factors influencing users' attitudes and preferences in the VR gaming context.

5.2. Practical implications

In this section, we discuss some practical implications for the industry of VR applications. It is advisable for marketing and product managers to pay attention to minimizing simulator sickness contributing factors during VR exposure to increase users' attitudes toward VR.

However, it is important not to overly obsess about this aspect as our data did not yield a significant effect from perceived simulator sickness on users' attitudes toward VR. The key focus should be on delivering captivating content and an overall high-quality VR experience, which will help individuals overcome their initial discomfort. Therefore, the focus should be on balancing between minimizing the negative effects of VR exposure and delivering engaging and enjoyable experiences of appropriate duration.

Furthermore, targeting individuals with higher scores in technophilia can be a strategic approach to drive VR adoption. These individuals are likely to have a positive attitude towards technology and may be more willing to ignore the potential discomfort associated with simulator sickness. Offering trial experiences to this target group can increase their likelihood of adopting VR applications. On the other hand, the influence of technophobia although does lower the willingness to adopt not-significantly, but further investigation is needed to better understand its impact.

Lastly, it is crucial to consider different age groups and price points when promoting VR adoption. Price was identified as a significant factor influencing willingness to adopt VR, suggesting that careful pricing strategies and offerings tailored to different age groups can play a vital role in overcoming adoption barriers. By making VR more accessible and affordable, it becomes more appealing to a broader range of potential users.

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Appendix A

Original 16 items questionnaire for measuring technophilia and technophobia participants answer.

Technophilia:

- I find technology to be an integral part of my daily life.
- I enjoy exploring and adopting the latest technological devices and gadgets.
- I consider myself an early adopter of new technologies.
- I feel a sense of satisfaction and fulfillment when using cutting-edge technology.
- I am excited about new equipment or technology.
- I'm afraid of being left behind if I cannot use the latest equipment or technology.
- I enjoy using new equipment or technology.
- I think it is necessary to teach young students about modern technology.

Technophobia:

- I avoid the use of new equipment and technology.
- I feel an irrational fear of new equipment or technology.
- I worry about the negative impact of technology on society.
- I find it challenging to keep up with the rapid changes in technology.
- I feel overwhelmed by the complexity of modern technology.
- I am concerned about the potential loss of privacy and security in a highly technological world.
- I feel uncomfortable when I use new equipment or technology.
- I love being away from screens for days.

Appendix B

The extracted factor for technophilia:

- I find technology to be an integral part of my daily life.
- I enjoy exploring and adopting the latest technological devices and gadgets.
- I enjoy using new equipment or technology.
- I think it is necessary to teach young students about modern technology.
- (Recoded - reversed) I feel uncomfortable when I use new equipment or technology.

The extracted factor for technophobia:

- (Recoded - reversed) I consider myself an early adopter of new technologies.
- (Recoded - reversed) I feel a sense of satisfaction and fulfillment when using cutting-edge technology.
- (Recoded - reversed) I am excited about new equipment or technology.
- I worry about the negative impact of technology on society.
- I find it challenging to keep up with the rapid changes in technology.
- I feel overwhelmed by the complexity of modern technology.
- I am concerned about the potential loss of privacy and security in a highly technological world.
- I love being away from screens for days.

Appendix C

Four items five-point scale measuring attitudes toward VR

- "I love the virtual reality gaming experience."
- "I feel comfortable after the experience."
- "I would like to play in virtual reality again."
- "Virtual reality creates such an outstanding experience."

Participants will indicate their agreement as:

1. Totally disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Totally agree

Appendix D

The MIsery SCale (MISC)

Symptoms		MISC
No problems		0
Some discomfort, but no specific symptoms		1
Dizziness, cold/warm, yawning, headache, tiredness, sweating, stomach / throat awareness, burping, blurred vision, salivation, … but no nausea	vague	2
	little	3
	rather	4
	severe	5
Nausea	little	6
	rather	7
	severe	8
	retching	9
Vomiting		10