HCI: Research into the Effects XR has on Users, an Exploratory Study on Apple Vision Pro

Panagiotis-Efstratios Chontas
Faculty of Computer Science
"Alexandru Ioan Cuza" University
Iasi, Romania
panagiotis.chontas98@gmail.com

Adrian Iftene
Faculty of Computer Science
"Alexandru Ioan Cuza" University
Iasi, Romania
adiftene@gmail.com

Sabin-Corneliu Buraga
Faculty of Computer Science
"Alexandru Ioan Cuza" University
Iasi, Romania
busaco@info.uaic.ro

ABSTRACT
Recent increases in Extended Reality (XR) headset sales suggest a growing consumer preference for Augmented Reality (AR)/Virtual Reality (VR) in home and institutional environments. As XR technology becomes mainstream and evolves, it is essential to examine its physical and mental impacts. While recent studies emphasize the positive effects of XR, this paper argues for investigating potential negative outcomes to ensure user well-being and ethical standards. This study involved young adults (ages 18-29) using the Apple Vision Pro headset within a visionOS environment, designed to encompass a range of user interactions. Questionnaires and health tests were conducted to evaluate participants. Findings indicate users' adeptness in interacting with XR technologies, particularly favoring experiences that simulate real-life environments in three dimensions. However, despite their familiarity with technology and extensive screen time, young adults experienced physical side effects early in the testing process. This research underscores the necessity of a balanced understanding of XR's implications to guide its development responsibly.

Author Keywords
Human Computer Interaction (HCI); Extended Reality (XR); visionOS; Apple Vision Pro; Augmented Reality (AR); Virtual Reality (VR); User Interface (UI).

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces. H.3.2. Information Storage and Retrieval: Information Storage.

General Terms
Human Factors; Design; Measurement.

DOI: 10.37789/ icusi.2024.10

INTRODUCTION
This research paper aims to contribute to the intersection of Human-Computer Interaction (HCI) and Extended Reality (XR), facilitating a comprehensive understanding of how users interact with, perceive, and are affected by this technology. XR is extensively applied across various industries, and its continued evolution necessitates a thorough comprehension of the underlying mechanisms, immediate and long-term effects of its use, and broader implications for users. It is crucial to understand how XR operates, including the integration of hardware and software, and the sensory and cognitive processes it engages, to maximize its potential benefits and mitigate adverse effects.

The motivation for this paper stems from the concern over the paucity of research on the potential side effects of XR headset use. Existing studies are limited, incomplete, and lack a deeper understanding of the short-term versus long-term effects on users' mental and physical health. In contrast, there is a substantial body of research focused on enhancing the technology's immersiveness and performance.

RELATED WORK
A selection of papers or studies with related work was based on rigorous evaluation of their research findings, insights, and significant conclusions that are instrumental in substantiating the hypothesis and proposition presented in this paper. These chosen works provide essential foundations and valuable perspectives that contribute to the overall argument and scholarly discourse on the subject matter at hand. Their inclusion serves to bolster the theoretical framework and empirical support underpinning the central thesis of this study.

In paper [1], the purpose was to investigate the potential impacts of VR technology on users, with a specific focus on the emotional side effects of VR gameplay. The research commenced with a preliminary survey designed to evaluate users' emotional responses during VR gameplay. The survey results indicated that certain VR scenarios could indeed evoke intense negative emotional reactions. Based on these findings, the researchers developed an interactive scenario intended to elicit low to moderate levels of negative emotion. Participants engaged with this scenario either in VR (using the HTC Vive) or on a laptop computer.

The comparative analysis revealed that participants in the VR condition reported higher levels of absorption in the scenario, which subsequently intensified their negative emotional responses. The results of this study underscore the potential for VR gameplay to elicit strong negative emotional responses, which could be detrimental to users if not appropriately managed.

In paper [2], the aim was to investigate the adverse symptoms experienced by users of Head-Mounted Displays (HMDs) in VR environments, despite ongoing advancements in VR technology. Traditional studies often rely on self-report measures, such as the Simulator Sickness Questionnaire (SSQ), to monitor these symptoms. However, the reliance on subjective measures may overlook certain adverse effects. This research seeks to address this gap by examining both visual and cognitive after effects of Head-Mounted Displays (HMDs) use and their correlation with reported sickness symptoms on the Simulator Sickness Questionnaire (SSQ). The study used an application-based approach, utilizing both visual and cognitive assessments before and after VR exposure. Participants were divided into two groups: the VR group (n = 27), who played a 30-minute VR table tennis game, and the control group (n = 28), who continued with their daily activities. Visual assessments focused on accommodation and vergence, while cognitive assessments measured reaction time and rapid visual processing. Results indicated significant changes in accommodation without corresponding changes in vergence, likely due to the decoupling of accommodation and vergence in VR environments. Notably, larger changes in accommodation were associated with more severe sickness symptoms, suggesting that this decoupling might have more adverse effects than previously understood. Additionally, the VR group exhibited slower cognitive decision times, although their movement times remained unaffected. This research underscores the potential negative impact of these aftereffects on users' subsequent real-world activities.

In paper [3], aimed to examine the effects of wearing VR head-mounted goggles on body sway in young adults. The research was designed to provide a comprehensive understanding of how VR technology influences postural stability under various conditions. Specifically, the study sought to compare body sway metrics across different states: wearing VR goggles with eyes open or closed, and whether the virtual scene is turned on or off. The study was divided into two experiments. The first experiment involved 44 young adults who were instructed to stand as still as possible on a force plate for 60 seconds across three trials in each of the following conditions: wearing VR goggles with eyes open and not wearing VR goggles with eyes open. The second experiment involved 15 young adults and examined body sway in three conditions: wearing VR goggles with eyes closed, not wearing them with eyes closed, and wearing them with eyes open, both with the virtual scene on and off. The study concluded that wearing VR head-mounted goggles increases body sway in young adults during standing postural tasks when their eyes are open. However, this effect is not observed when the eyes are closed or when the VR scene is turned off, suggesting that visual input from the VR environment significantly influences postural control.

These studies collectively underscore that while XR technologies offer numerous benefits, they also pose several potential negative impacts on users. Emotional distress, visual and cognitive disturbances, and physical instability are significant concerns that need addressing. As XR continues to evolve and integrate into various sectors, it is crucial to balance the advancements with thorough research into these adverse effects to ensure that there are established comprehensive guidelines and regulatory frameworks to ensure user safety and knowledge of potential effects. Understanding and mitigating these negative impacts will be critical for the responsible adoption and long-term success of XR technologies.

PROPOSED SOLUTION

This study seeks to determine whether these side effects are observable or latent, temporary or permanent, distinguishable or subtle, and mild or severe. By examining the physical, cognitive, and emotional impacts of XR headset usage, this research endeavors to provide a comprehensive understanding of the risks and benefits associated with this technology.

Research question

The research question formulated to guide this study aims to provide a comprehensive understanding of the implications of XR headset usage. The specific question addressed in this paper is: *What are the immediate effects of using an XR headset?* This inquiry is crucial as it seeks to identify and characterize the direct impacts on users, encompassing a range of potential outcomes, from physical and cognitive effects to emotional and sensory experiences.

Research hypothesis

The proposed hypothesis for this study is as follows: *If young adults (ages 18-29), who are early adopters of new technologies and spend a significant amount of time using smart devices (such as smartphones, tablets, smartwatches, gaming consoles, computers, and smart TVs), exhibit perceptible side effects after using an XR headset, this would provide clear evidence that these devices have adverse effects on users.* Consequently, this would warrant further exploration into the specific side effects and their impact on the mental and physical health of users. This hypothesis aims to establish a foundational understanding of the potential health implications associated with prolonged use of XR technology among a demographic already accustomed to extensive screen exposure.

Research Proposal

Based on the proposed hypothesis, a sample of 15 individuals aged 18-29 were selected for the study. This cohort included participants with varying levels of prior experience with XR headsets. Another criteria included having no eye issues or a vision correction within the range of -1.5 to +1.5 diopters, given that the Apple Vision Pro headset does not accommodate personal prescription glasses. This criterion ensured that participants could see adequately, even with minor visual impairments, without their prescription glasses. Additionally, participants were required to be either in their senior year of high school, university students, or holders of a bachelor's degree. This criterion was set to ensure that the focus group consisted of individuals with significant experience using devices for extended periods, typical of their academic pursuits.

The group was selected with an emphasis on balanced representation from both genders (6 females, 8 males) and a predominance of participants from the IT&C sector. This focus on IT&C professionals aimed to incorporate individuals with high levels of experience, expertise, and resilience regarding prolonged device use for work and study. However, participants from other sectors were also included to provide a diverse range of perspectives and to observe differences in user experience across varied backgrounds. To ensure the accuracy of this research and minimize any external or unwanted influences, an XR application (native visionOS for Apple Vision Pro) was developed specifically for this study. This application was meticulously designed and created to encompass a comprehensive range of user interactions that can be performed within an XR headset. By providing a complex and thorough experience, the resulting feedback will be as precise and reliable as possible. The controlled environment offered by this custom application enabled a more accurate assessment of the potential side effects of XR headset usage, thereby enhancing the validity of the study's findings. To ensure the collection of comprehensive data for a more accurate conclusion, all participants completed anonymous questionnaires both before and immediately after testing the XR application. The pre-test questionnaire will include general demographic questions and inquiries about any pre-existing health conditions that could potentially be affected by interaction with the XR device. The post-test questionnaire will assess the participants' experiences, including any perceived changes in their well-being or exacerbation of health issues resulting from the XR interaction.

Used Apparatus

For this study, a commercially available Apple Vision Pro 1TB with a Solo Knit Band - M and a Light Seal - 25W was used. At the time of the study, this device was available only in the USA. Additionally, a commercially available MacBook Air M2, 16GB running Sonoma 14.5 was utilized for real-time mirroring of the Apple Vision Pro, allowing the researcher to observe the participants' experience. In this study, three medical measures were recorded for each participant: blood pressure, heart rate, and oxygen saturation. These measurements were obtained using a Pulse Oximeter and an Arm Blood Pressure Monitor. Specifically, the ChoiceMMed Fingertip Pulse Oximeter MD300CN330 and the Assista Arm Blood Pressure Monitor, both commercially available, were used for this purpose.

Figure 1. Apple Vision Pro presentation image

Questionnaire Design

This research was designed to incorporate three distinct questionnaires: a pre-test, a mid-test, and a post-test. Each questionnaire serves a unique purpose in collecting essential data from the study participants at different stages of their experience. The pre-test questionnaire is administered before participants engage with the XR device, the mid-test questionnaire consists of questions posed by the researcher during the experience, and the post-test questionnaire is completed by the participants after the testing session.

Pre-test Questionnaire

The pre-test questionnaire was designed to gather general information about the participants before they enter the testing phase with the XR device. This questionnaire collects data on any health issues that could potentially be exacerbated by the XR experience, demographic details, the duration and type of smart device usage, and participants' opinions on new technologies. The questionnaire is created using Google Forms and shared with participants via a QR code, which directs them to the form. Utilizing Google Forms facilitates faster completion, simplifies the process for participants, and enables easy analysis through built-in statistical tools provided by the Google Forms interface. Notably, the questionnaire consists of short and straightforward questions (e.g., Yes/No), enhancing the participant experience while ensuring the necessary information is obtained. The questions are carefully crafted to elicit clear and concise responses that provide valuable insights into the participants' thoughts, feelings, and understanding.

Mid-test Questionnaire

The mid-test questionnaire was designed to systematically capture participant experiences and perceptions during their engagement with the Extended Reality (XR) environment. Implemented via a comprehensive Google Form, it records detailed interactions with the native visionOS app scenes to facilitate future evaluation of the study. The questionnaire solicited participant feedback on emotional and physical responses to using the Extended Reality (XR) device and engaging with the experiences presented. Additionally, data from the Pulse Oximeter and Arm Blood Pressure Monitor are incorporated into this form. Importantly, the researcher adds data to the Google Form in real-time as the testing session progresses, ensuring that all interactions and responses are accurately documented during the ongoing testing phase. These responses play a critical role in understanding participant perceptions and interactions within the XR environment.

Post-test Questionnaire

The post-test questionnaire aimed to systematically collect participant feedback regarding their experiences after engaging with the Extended Reality (XR) environment. It gathered information on potential physical health impacts, feelings of disorientation, emotional responses during the experience, duration of engagement, likelihood of recommending the technology to others, overall perception of the experience, and opinions on prolonged use of such technologies. This data is crucial for comprehensively understanding participant sentiments and evaluating the potential effects of XR technology on users.

Procedure

This research was conducted at the Faculty of Computer Science Iasi, on the 7th floor, room C903, designed as a typical classroom with desks, a teacher's desk, and a chalkboard. The participant's chair was positioned centrally, facing the desks with the chalkboard behind, ensuring a safe environment with a minimum distance of 2 meters surrounding. The Researcher was stationed at the teacher's desk equipped with necessary materials including a laptop, while essential tools such as the filming phone, health measurement devices, and XR headset were strategically placed on separate desks for easy access during participant sessions.

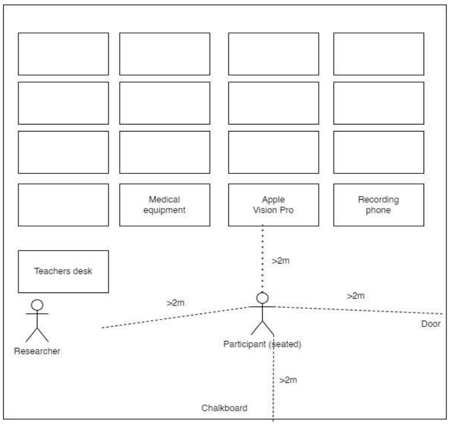

Figure 2. Research room arrangement.

A standardized protocol was followed for each participant upon entering the research room (classroom). Initially, participants were briefed closely by the researcher on the Apple Vision Pro, covering its hardware, design, functionalities, and features. Following this, a printed consent form was provided, verbally explaining the research process, participant rights, and the requirement for truthful data provision upon signing. Upon completion, participants accessed the Pre-Test Questionnaire via a provided QR code on a Google Form.

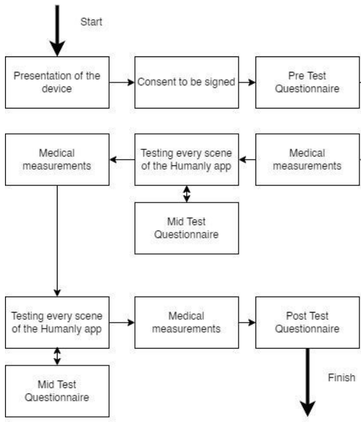

Figure 3. Research flow diagram - step by step

Subsequently, medical measurements including oxygen saturation, heart rate, and blood pressure were taken by the researcher using appropriate equipment. Participants then proceeded to put on the Extended Reality (XR) headset (Apple Vision Pro) and complete the setup process guided by the headset's software, with the researcher monitoring the process via laptop from the teacher's desk nearby. Upon launching the native visionOS app, the researcher engaged participants with questions from the Mid-Test Questionnaire after each scene. Following the initial immersive experience, participants were instructed to wait for medical measurements to be retaken and noted by the researcher before continuing. Throughout the session, additional questions were posed by the researcher. Upon completion of all app scenes, participants removed the headset, remaining in place for a minimum of 2 minutes while their heart rate, oxygen saturation, and blood pressure were again recorded. Upon concluding the session, participants were directed to complete the Post-Test Questionnaire via a QR code, signifying the end of their participation.

Used Technologies

The development of the native visionOS application utilized in this research necessitated the use of the Swift programming language. Additionally, it incorporated the ARKit and RealityKit frameworks to enable advanced augmented reality functionalities. Visual editors such as Reality Composer Pro and Blender were used to design and refine the interactive 3D environments. This combination of tools and frameworks ensured a robust and immersive user experience, crucial for accurately evaluating the interaction dynamics and physiological responses of participants in the study.

General Flow

The structure of the application comprises 18 distinct stages or scenes. Two of these stages serve as bookends: an introductory page at the beginning and a thank you page at the end. The remaining 16 stages consist of various XR experiences designed to engage users with a broad spectrum of available interactions. These stages aim to thoroughly explore user engagement and interaction within the XR environment. Scenes are arranged in a prescribed sequence as depicted in the app. To proceed to the subsequent scene, the user simply needs to press the “Next” button located in the lower right corner of their field of view.

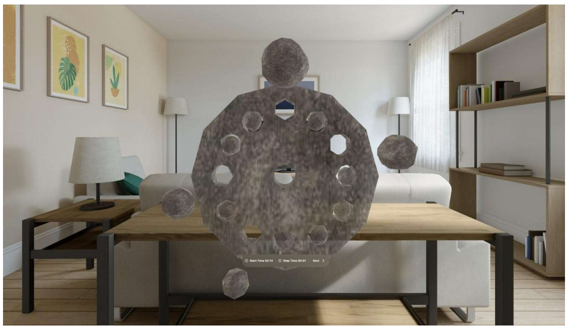

Figure 4. Animation with 3D model from the app

Architecture

Applications within VisionOS employ three distinct types of viewports to deliver their content: Windows, Volumes, and Spaces.

- Windows manifest as floating planes within the 3D environment, offering functionalities such as repositioning, resizing, and closure. This design enables users to interact with content akin to physical objects within their surroundings.
- Volumes extend beyond simple planes by incorporating depth to showcase 3D content within a shared space. They enhance immersion and feature controls for repositioning and closure, making them suitable for presenting intricate 3D models or interactive elements that benefit from spatial depth.
- Spaces encompass the entirety of the user’s environment and encompass two main types: Shared Spaces and Immersive Spaces. Shared Spaces facilitate collaborative interactions, while Immersive Spaces are optimized for applications emphasizing extensive 3D content, utilizing the surrounding environment to its fullest potential without the confines of a limited viewport like Volumes. To integrate UI elements from SwiftUI, developers must first create Attachments in Reality View, establishing links between these UI elements and the 3D content displayed.

The application comprises nine distinct Reality View scenes, all integrated into a singular Immersive Space. The Form Scene necessitates a separate window featuring a basic View within this space due to specific components that exclusively function within windows. Transitions between these scenes are orchestrated by the SpatialManager, a singleton entity entrusted with displaying or concealing the current scene. This managerial role involves employing a modifier to regulate the visibility of each scene according to its operational state.

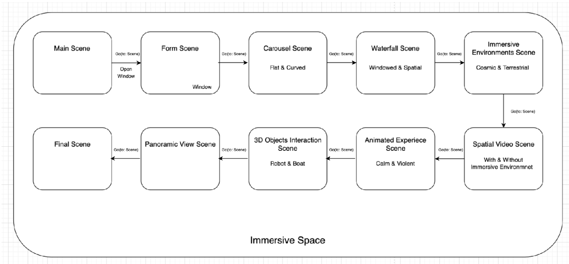

Figure 5. Navigation flow of the native visionOS app

Each scene is distinguished by a descriptor, and these descriptors are systematically arranged in a sequential list to correspond with the user’s journey through the application. The SpatialManager utilizes this organized list to facilitate fluid navigation between scenes. Each scene incorporates a loader housing its respective view, where a modifier dynamically adjusts the view’s visibility based on its activation status. This method ensures smooth transitions and optimizes resource utilization, thereby enhancing the overall user experience.

RESEARCH EVALUATION

The study has addressed the research question “*What are the immediate effects of using an XR headset*?” and tested the hypothesis that young adults (ages 18-29), characterized as early adopters of technology with extensive daily interaction across various smart devices, may experience perceptible side effects following XR headset use. The findings align with this hypothesis, revealing that participants indeed reported symptoms such as eye fatigue, dizziness, and nausea after exposure to XR environments. Despite their technological familiarity, participants generally preferred 3D interactions resembling real-world physics, though discomfort was noted post-use. Physiological measurements (heart rate, blood pressure, oxygen saturation) remained stable throughout, indicating no immediate health risks.

Notably, participants expressed a willingness to recommend the XR experience, indicating strong acceptance and interest in future adoption of XR technologies despite these observed mild adverse effects. The applied methodology, encompassing pre-test and post-test questionnaires, intermittent medical measurements, and ongoing mid-test assessments, effectively captured these insights across different phases of the research process.

Results

Notably, within 4 to 7 minutes of using the research application, 20% of participants reported experiencing discomfort. This indicates that discomfort began to manifest within 7 to 13 minutes of the headset being placed on their heads. Additionally, 13.3% of participants reported eye fatigue, and 6.7% experienced dizziness. When exposed to fully immersive environments, 26.7% of participants indicated feelings of fear, while 13.3% reported discomfort. Further questioning revealed that 6.7% of participants experienced a fear of heights, and 20% acknowledged a sensation of falling.

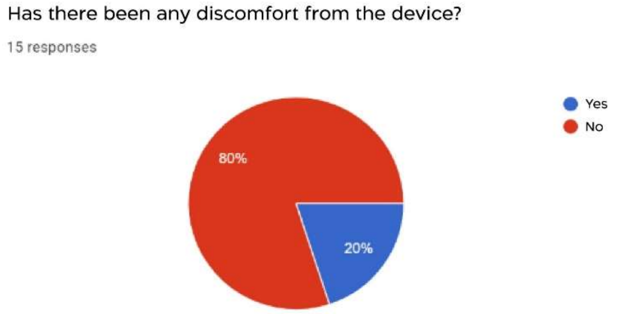

Figure 6. Response from the participants related to discomfort

Moreover, 40% of participants believed their perception had been affected, and 20% expressed feelings of unsafety despite being aware that they were physically in a room and seated on a chair. The experience with 3D animations also raised concerns: 33.3% of participants attempted to evade, 33.3% blinked in fear, and 46.7% expressed a preference for maintaining visibility of their surrounding environment.

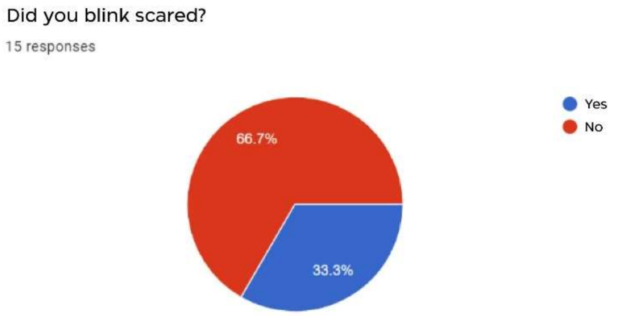

Figure 7. Response from the participants related to blinking.

Additional observations revealed that 93.3% of users found it easy and quick to navigate the XR environment. Among the participants, 60% preferred using voice commands for typing, and over 85% favored 3D-designed experiences over 2D interfaces. All participants (100%) expressed a high level of enjoyment in interacting with 3D models, quickly adapting to the tasks of placing, rotating, and resizing them, describing these interactions as natural and intuitive.

However, 60% of participants indicated a preference for viewing videos through their customary mediums rather than in an immersive environment. An alarming increase in reported discomfort was noted by the end of the session, rising to 26.7%, with 20% experiencing eye fatigue, 13.3% indicating dizziness, and 6.7% reporting nausea.

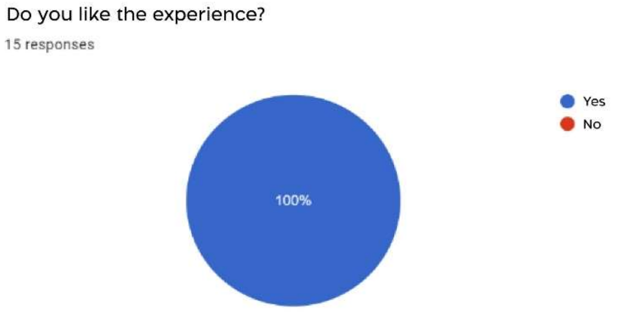

Figure 8. Response from the participants related to 3D models

Despite these findings, 100% of participants stated they would recommend the XR experience to others and expressed a willingness to try it again. This supports the hypothesis and demonstrates that participants, selected for their openness to new technologies, remained unbiased despite experiencing certain adverse effects. Furthermore, this indicates the technology's potential for widespread acceptance due to its unique attributes and qualities.

These results highlight the physical and psychological effects encountered by participants during the XR experience, suggesting that even individuals highly accustomed to technology and prolonged screen time can experience significant side effects when using XR headsets. The theoretical implications of these findings underscore the necessity for establishing safety guidelines that inform users about potential side effects associated with XR technologies. Furthermore, these findings suggest a critical need for ongoing research and technological advancements aimed at mitigating or eliminating these effects altogether.

Conclusions

As XR technology continues to advance rapidly with innovations, new concepts, and new devices, it is attracting significant attention from users across various age groups and backgrounds. The expanding XR market is creating a substantial user base that will engage with this technology on a daily basis. This study provides an initial exploratory observation regarding the presence of negative side effects associated with the use of XR headsets. Notably, these effects can manifest even in early adopters who are accustomed to prolonged exposure to screens and technology.

The findings of this research underscore the importance of further in-depth investigation into the physiological and psychological impacts of XR technology. For a more comprehensive understanding, this paper advocates for advanced research that integrates medical, physiological, and technical approaches to yield clearer and more precise results. By doing so, future studies can better inform guidelines and safety measures to enhance user experiences and mitigate potential adverse effects associated with XR device usage.

Recommendations

This paper proposes that the observation of side effects following the use of XR devices should prompt increased interest and investigation from research teams, XR developers, and policymakers. A collaborative effort among these stakeholders, supported by in-depth and interdisciplinary research, is essential to generate clear, robust, and actionable results. Such findings could inform the establishment of comprehensive guidelines and safety regulations for the use of XR technology.

By undertaking a unified and rigorous research approach, the goal is to achieve a deeper understanding of the physiological and psychological effects of XR devices. This would not only enhance the safety and user experience but also contribute to the development of best practices for XR technology implementation. Should the research confirm the necessity for regulatory measures, these would provide a framework for the safe and controlled evolution of XR technologies, ensuring their stability and facilitating broader acceptance and integration into daily life.

Future work

This research study represents an initial exploration that lays the groundwork for a comprehensive and conclusive investigation into XR technology. A potential future direction could encompass a multifaceted examination involving advanced equipment and interdisciplinary expertise across various fields. Expanding the participant pool to encompass diverse age groups and including multiple types of XR devices, including those in development, could provide a broader spectrum of reactions and interactions, yielding more definitive insights into the effects on users. Incorporating experts from neuroscience, neurology, cardiology, ophthalmology, psychiatry, and psychology would enhance the study's credibility and contribute to establishing it as a pivotal reference in the XR research community. From a medical perspective, using real-time monitoring devices such as Electroencephalogram (EEG) for brain activity, Electrocardiogram (EKG) for cardiovascular responses, and specialized ophthalmic tests like B-scan ultrasound, ultrasound pachymetry, and Humphrey Visual Field Analyzer could offer detailed insights into physiological responses during XR headset usage. Furthermore, integrating psychological assessments such as the Minnesota Multiphasic Personality Inventory (MMPI) test for mental health evaluations, the Hamilton Anxiety Scale for anxiety symptoms, and phobia tests to gauge fear responses would provide a comprehensive understanding of the psychological impacts of XR experiences.

These proposed advancements would elevate the current research into a sophisticated and nuanced study, capable of addressing multifaceted aspects of XR technology. By pursuing these avenues, this study could serve as a pioneering resource, guiding future developments and regulatory considerations within the XR community.

REFERENCES

1. R. Lavoie, et al. (2020) "Virtual Experience, Real Consequences: The Potential Negative Emotional Consequences of Virtual Reality Gameplay." *Virtual Reality*, vol. 25, no. 69-81, 2 Apr. 2020, link.springer.com/article/10.1007/s10055-020-00440-y, https://doi.org/10.1007/s10055-020-00440-y.
2. A. Szpak, S. C. Michalski, D. Saredakis, C. S. Chen, T. Loetscher (2019) "Beyond Feeling Sick: The Visual and Cognitive Aftereffects of Virtual Reality," in IEEE Access, vol. 7, pp. 130883-130892, 2019, doi: 10.1109/ACCESS.2019.2940073.
3. L.F.I. Imaizumi, et al. (2020) "Virtual Reality Head-Mounted Goggles Increase the Body Sway of Young Adults during Standing Posture." Neuroscience Letters, vol. 737, 15 Oct. 2020, p. 135333, www.sciencedirect.com/science/article/pii/S0304394020306030?via%3Dihub#sec0035, https://doi.org/10.1016/j.neulet.2020.135333.
4. M. Trapp, et al. (2014) "Impact of Mental and Physical Stress on Blood Pressure and Pulse Pressure under Normobaric versus Hypoxic Conditions." *PLoS ONE*, vol. 9, no. 5, www.ncbi.nlm.nih.gov/pmc/articles/PMC4015896/, https://doi.org/10.1371/journal.pone.0089005.
5. R. Avram, et al. "Real-World Heart Rate Norms in the Health EHeart Study." Npj Digital Medicine, vol. 2, no. 1, 25 June 2019, www.ncbi.nlm.nih.gov/pmc/articles/PMC6592896/, https://doi.org/10.1038/s41746-019-0134-9.
6. N. Sadamali Jayawardena, et al. (2023) "The Persuasion Effects of Virtual Reality (VR) and Augmented Reality (AR) Video Advertisements: A Conceptual Review." *Journal of Business Research*, vol. 160, May 2023, p. 113739, https://doi.org/10.1016/j.jbusres.2023.11373
7. Kaplan, A. D., Cruit, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2021). The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. Human factors, 63(4), 706-726.
8. Riva, G., Baños, R. M., Botella, C., Mantovani, F., & Gaggioli, A. (2016). Transforming experience: the potential of augmented reality and virtual reality for enhancing personal and clinical change. Frontiers in psychiatry, 7, 164.
9. Souchet, A. D., Philippe, S., Lourdeaux, D., & Leroy, L. (2022). Measuring visual fatigue and cognitive load via eye tracking while learning with virtual reality head-mounted displays: A review. International Journal of Human-Computer Interaction, 38(9), 801-824.
10. Venkatesan, M., Mohan, H., Ryan, J. R., Schürch, C. M.,Nolan, G. P., Frakes, D. H., & Coskun, A. F. (2021). Virtual and augmented reality for biomedical applications. Cell reports medicine, 2(7).
11. Apple Inc. "Apple Vision Pro." Apple, 2024, www.apple.com/apple-vision-pro/.