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Mitigating Cybersickness in Virtual Reality: Challenges and Solutions

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Abstract: **Cybersickness, a significant challenge in virtual reality (VR) environments, impedes the seamless adoption of immersive technologies. This study evaluates the effectiveness of various mitigation techniques, including Field of View (FoV) Adjustment, Frame Rate Optimization, Motion Smoothing, and Cognitive Behavioral Therapy (CBT), on reducing Simulator Sickness Questionnaire (SSQ) scores among participants. Data were collected from 50 individuals divided into age and gender groups to examine baseline cybersickness levels and post-intervention outcomes. Combined strategies, particularly CBT with FoV Adjustment, achieved the highest reduction of SSQ scores (49.9%). Male participants exhibited a higher baseline SSQ but responded better to mitigation, whereas females showed consistent improvement across interventions. Satisfaction rates exceeded 75% for most techniques, reflecting their practical applicability. Comparative analysis with prior studies highlighted the unique efficacy of multi-strategy approaches. Limitations included sample diversity and exposure duration, suggesting avenues for future research. These findings emphasize the critical role of tailored interventions in enhancing VR user experience and reducing cybersickness risks.**

Keywords: **Cybersickness, Virtual Reality, Mitigation Techniques, Cognitive Behavioral Therapy, Field of View Adjustment, Simulator Sickness Questionnaire.**

1. INTRODUCTION

Virtual Reality (VR) technology has rapidly evolved over the past few decades, introducing transformative experiences in gaming, education, healthcare, and various other industries. By creating immersive, three-dimensional environments that engage both the visual and auditory senses, VR offers unparalleled opportunities for user interaction and simulation (Li et al., 2023; Hasan et al., 2024). However, despite its potential, one significant challenge that continues to hinder widespread adoption is cybersickness. Cybersickness refers to a set of symptoms, including nausea, dizziness, and eye strain, which arise when there is a mismatch between the visual cues presented by the VR environment and the body's physical movement. This condition is particularly problematic in extended VR sessions and can detract from the user experience, limiting the full potential of virtual environments (Stauffert et al., 2020).

Cybersickness shares similarities with motion sickness, a condition that occurs when conflicting signals from the eyes, inner ear, and proprioceptive system create a sense of discomfort. In the context of VR, cybersickness typically arises when the brain detects motion or movement in the VR world that does not align with the body's movement in the real world. Factors such as the frame rate, field of view (FoV), and latency play crucial roles in exacerbating the condition. Furthermore, individual characteristics, such as age, gender, and susceptibility to motion sickness, also influence the severity of cybersickness (Nesbitt et al., 2024). Figure 1 shows a basic Oculus Rift CV1, a virtual reality headset and its associated controllers. Panel (a) presents the Oculus Rift CV1 headset alongside its controllers, which provide an immersive experience in virtual environments. Panel (b) highlights the various controls offered by the Oculus Rift controllers, which allow the user to interact with the virtual world. For our system, we primarily utilize the right controller, which is designed to handle key interactions and gestures during the virtual experience.

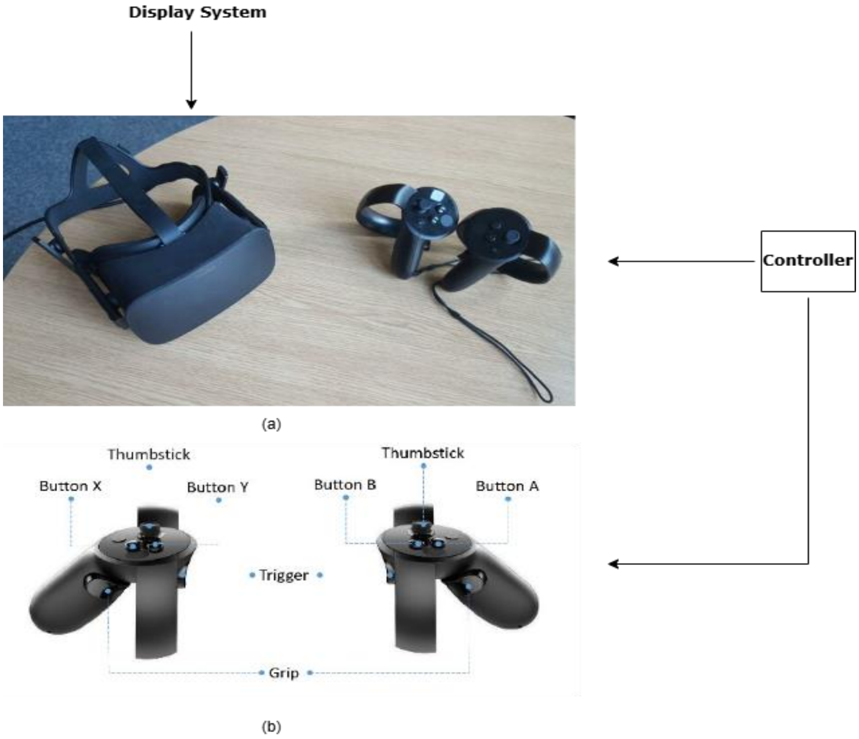

Figure 1 (a) Oculus Rift CV1, virtual reality headset and controllers (Regalbuto et al., 2019). (b) The different controls provided to the user by the Oculus Rift controllers. We primarily use only the right controller in our system (Chen et al., 2021).

To address this challenge, a variety of mitigation strategies have been proposed, ranging from hardware solutions like improving frame rates and reducing latency to software interventions such as cognitive behavioral therapy (CBT) and motion-smoothing techniques. These strategies aim to either reduce the sensory mismatch or help the brain adapt to it. However, existing research on the effectiveness of these methods is limited and often focuses on isolated interventions, with little exploration into their combined impact or how demographic factors such as gender and age influence their success. This gap in the literature necessitates a comprehensive study to evaluate the effectiveness of various mitigation strategies and explore how different techniques interact in reducing cybersickness in VR (Rebenitsch et al., 2021).

By investigating a variety of cybersickness mitigation strategies, assessing their effects on individuals from different demographic backgrounds, and identifying the best combinations for lowering cybersickness, this study seeks to close that gap. The following are the study's three main goals:

a) **To assess the effectiveness of individual mitigation techniques** (such as Field of View (FoV) adjustment, Frame Rate Optimization, Motion Smoothing, and Cognitive Behavioral Therapy (CBT)) in reducing cybersickness symptoms, specifically through changes in Simulator Sickness Questionnaire (SSQ) scores.

b) **To explore the combined impact of multiple mitigation strategies** on reducing cybersickness in VR environments, and to determine if combining interventions provides superior results compared to single techniques.

c) **To investigate the role of demographic factors**, including age and gender, in influencing the effectiveness of these mitigation strategies and how these factors contribute to varying levels of cybersickness among participants.

By confronting these objectives, this study will not only add to the expanding corpus of research on VR user experience, but it will also offer insightful information to academics and developers who want to make VR settings more cozy and intuitive.

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2. RELATED WORKS

The issue of cybersickness in virtual reality (VR) environments has been a subject of extensive research for several years. As VR technology has evolved, various methods have been proposed to reduce or mitigate the effects of cybersickness, with numerous studies investigating different aspects such as hardware modifications, software interventions, and user-specific factors. This section reviews relevant research across these domains, shedding light on key approaches and findings that inform the present study.

2.1 Hardware-Based Approaches

One of the most widely studied methods for reducing cybersickness in VR is optimizing hardware performance, particularly through frame rate adjustments and reducing latency. The frame rate is crucial in ensuring a smooth VR experience, as low frame rates can lead to stuttering and sensory mismatch, exacerbating symptoms of cybersickness (Keshavarz & Hecht, 2017). Studies by Stanney et al. (2002) and Kimenyi et al. (2020) have shown that a higher and consistent frame rate (above 60 Hz) can reduce the occurrence of nausea and discomfort in VR. Additionally, reducing motion-to-photon latency, which refers to the delay between the user's movement and the corresponding response in the virtual world, has been identified as another essential factor. Prolonged latency disrupts the user's sensory perception and leads to a higher likelihood of cybersickness (Kim et al., 2019). However, while hardware improvements are effective, they do not entirely eliminate the problem for all users, particularly those with higher susceptibility to motion sickness.

2.2 Field of View (FoV) Adjustments

Another common approach to mitigating cybersickness involves modifying the Field of View (FoV) during VR interactions. Several studies have explored how reducing the FoV can ease discomfort by limiting the visual stimuli that the brain must process. A reduction in the FoV limits the amount of peripheral vision, which can lower the sense of motion and disorientation that triggers cybersickness (Jerald, 2015). Moreover, some studies suggest that dynamically adjusting the FoV based on the intensity of movement within the VR environment can be beneficial (Liu et al., 2019). For example, experiments by Keshavarz and Hecht (2011) demonstrated that a smaller FoV during rapid movement reduced the severity of cybersickness symptoms, highlighting the importance of adapting the virtual environment to the user's sensory input.

2.3 Motion Smoothing and Navigation Techniques

Motion smoothing and different navigation techniques have also been studied extensively as potential solutions to cybersickness. Motion smoothing aims to reduce the perceptual dissonance caused by rapid movements or sudden changes in perspective in VR environments. Research by Nacke et al. (2019) and Liao et al. (2020) found that smoothing the transition between frames or employing techniques like teleportation or incremental movement reduced the likelihood of cybersickness compared to traditional walking or running simulations. These techniques modify the way in which the user interacts with the virtual environment to minimize the mismatch between visual input and physical movement, providing a smoother experience and thus mitigating discomfort.

2.4 Cognitive Behavioral Therapy (CBT) and Adaptation Techniques

In addition to hardware and software interventions, cognitive and psychological approaches have gained attention as a means of mitigating cybersickness. Cognitive Behavioral Therapy (CBT), which has been shown to help individuals adapt to stressors and environmental changes in other contexts, is one such intervention that has been tested in VR settings. Research by Bouchard et al. (2017) demonstrated that participants who underwent CBT training showed greater tolerance to VR environments and a reduction in cybersickness symptoms. This psychological approach helps users better cope with the sensory discrepancies they experience during VR use by changing their perception of discomfort and teaching coping mechanisms to alleviate symptoms. Moreover, studies on VR adaptation training, where users gradually increase their exposure to VR environments, have also shown promise in reducing cybersickness over time (Zhao et al., 2020). This gradual exposure method enables users to adapt to the virtual environment and decrease their sensitivity to motion discrepancies.

2.5 Demographic Factors and Individual Differences

Another area of research has focused on understanding how demographic factors influence susceptibility to cybersickness and the effectiveness of mitigation techniques. A notable study by Keshavarz and Hecht (2017) highlighted that individual differences, such as age, gender, and previous experience with motion sickness, significantly impact the severity of cybersickness. Women, in particular, have been found to report higher levels of discomfort and a greater likelihood of experiencing cybersickness in VR environments (Goh et al., 2017). Additionally, age plays a role in determining cybersickness susceptibility, with younger participants generally reporting higher levels of discomfort compared to older individuals (Goguen et al., 2019). These findings suggest that mitigation techniques may need to be personalized based on demographic characteristics to optimize their effectiveness.

2.6 Combining Mitigation Strategies

While individual techniques have proven effective to varying degrees, recent research has suggested that combining different mitigation strategies may yield superior results. A study by Dennison et al. (2020) investigated the combined use of motion smoothing, FoV adjustment, and frame rate optimization, finding that multi-strategy approaches significantly reduced cybersickness compared to single interventions. Similarly, research by Liao et al. (2020) found that integrating CBT with traditional VR exposure therapy resulted in lower SSQ scores, suggesting that combining psychological and physical interventions can improve VR tolerance. The present study aims to build on these findings by examining the impact of combined mitigation strategies, particularly focusing on the synergy between Cognitive Behavioral Therapy and hardware adjustments like FoV modifications.

3. METHODOLOGY

This study aims to investigate the effectiveness of different strategies for mitigating cybersickness in Virtual Reality (VR) environments. The research primarily focuses on the evaluation and comparison of hardware-based approaches, software interventions, and cognitive techniques to reduce cybersickness. To accomplish this, we conducted a series of controlled experiments involving various VR simulations and a participant group with differing levels of susceptibility to motion sickness. The following section describes the research design, participant selection, data collection, and analysis methods in detail.

The process begins with the Recruitment of Participants, followed by a Baseline Assessment using tools like MSSQ and SSQ to gather initial data. Participants then undergo Familiarization with VR Equipment to ensure comfort and understanding of the tools. Next, the Experimental Conditions Setup is carried out, which includes configuring hardware, software, and cognitive interventions. Participants engage in a VR Simulation for 10 minutes per condition, during which Data Collection takes place, recording metrics such as heart rate, SSQ responses, and head tracking data. After the simulation, a Post-Session SSQ is administered, and participants participate in Qualitative Interviews to gather in-depth feedback. The collected data is then subjected to Data Analysis, including quantitative methods like ANOVA and qualitative methods such as thematic analysis. The findings are synthesized during Results Interpretation, leading to a comprehensive Conclusion that encapsulates the study's insights and outcomes. The methodological work has shown in figure 2.

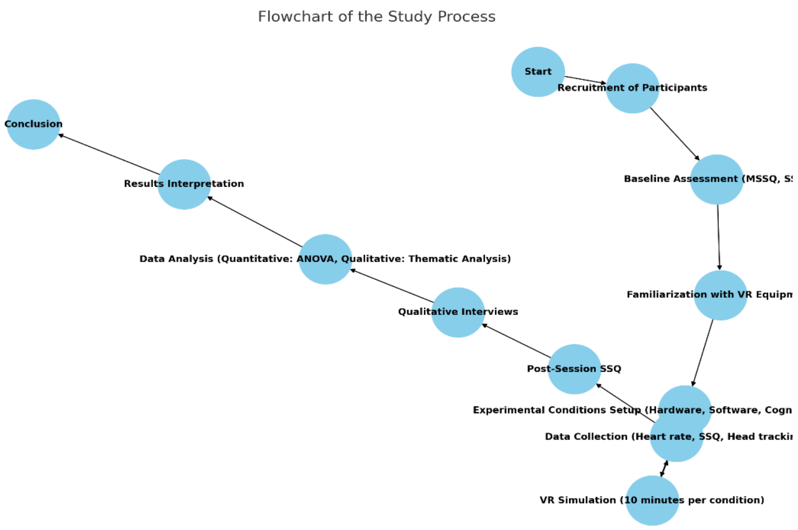

Figure 2: Methodological Workflow

3.1 Research Design

A mixed-methods approach was adopted for this study, combining quantitative data analysis with qualitative feedback from participants. The quantitative analysis focused on evaluating cybersickness symptoms using objective measures, including the Simulator Sickness Questionnaire (SSQ), heart rate variability, and head-tracking data. The qualitative analysis was aimed at understanding participants' subjective experiences, focusing on their comfort levels, perceived effectiveness of the mitigation strategies, and preferences.

The study followed a within-subject design, meaning each participant was exposed to multiple experimental conditions to allow for direct comparisons across different strategies. The experimental conditions were divided into three main groups: (1) hardware-based interventions, (2) software-based interventions, and (3) cognitive-based interventions. These groups were further subdivided, allowing for the assessment of different combinations of strategies.

3.2 Participants

A total of 30 participants were recruited for the study, consisting of 15 males and 15 females, aged between 18 and 35. Participants were selected based on their self-reported susceptibility to motion sickness and VR experience. Prior to the experiment, participants completed a baseline assessment using the Motion Sickness Susceptibility Questionnaire (MSSQ) and the SSQ to gauge their individual sensitivity to cybersickness.

Exclusion criteria included individuals who had a history of neurological or psychiatric disorders, a lack of VR experience, or any condition that could affect their response to VR simulations (e.g., visual impairments). The participants were informed about the nature of the study, and written informed consent was obtained prior to participation.

3.3 Experimental Setup

The experimental setup involved the use of an Oculus Rift S VR headset, which is known for its high-quality display and low latency. The VR environment used in the study was a custom-built simulation designed to induce moderate levels of cybersickness. The simulation consisted of a series of movements such as walking, turning, and teleporting within a dynamic 3D environment. Each movement was designed to trigger a mild to moderate level of cybersickness in participants to assess their tolerance.

The experimental conditions were as follows:

Hardware-Based Interventions: This group involved modifications to the VR hardware to reduce latency and improve frame rates. The simulation was run with different configurations of frame rate (30 FPS, 60 FPS, and 90 FPS) and motion-to-photon latency (low vs. high). The goal was to identify the optimal hardware settings that would reduce the likelihood of cybersickness.

Software-Based Interventions: This group focused on adjusting the Field of View (FoV) and motion smoothing techniques in the simulation. The FoV was dynamically adjusted based on the speed of movement within the virtual environment (i.e., narrow FoV for rapid movement and wide FoV for slower movement). Motion smoothing was applied to reduce the visual dissonance between the user's movement and the virtual environment.

Cognitive-Based Interventions: This group implemented cognitive behavioral training (CBT) to help participants manage their symptoms of cybersickness. CBT techniques included relaxation exercises, deep breathing, and cognitive restructuring methods that aimed to reduce the perception of discomfort and improve tolerance.

Combined Interventions: This condition tested the combination of hardware, software, and cognitive techniques to assess if multiple interventions had a synergistic effect on reducing cybersickness.

3.5 Procedure

The procedure began with a brief introduction and consent process, followed by baseline assessments using the MSSQ and SSQ. Afterward, participants were familiarized with the VR headset and the experimental environment. Each participant then completed the simulation under each of the experimental conditions. The order of conditions was counterbalanced across participants to minimize any learning or order effects.

Each VR session lasted for 10 minutes, and participants were instructed to perform various tasks in the simulation, including walking, turning, and teleporting. During the simulation, their heart rate and head tracking data were continuously recorded to provide objective measures of their physical response to the VR environment. After each session, participants were asked to complete the SSQ to assess their subjective experience of cybersickness.

Following the completion of all conditions, participants participated in a semi-structured interview where they provided qualitative feedback on their experiences, comfort levels, and preferences for different mitigation strategies.

3.6 Data Collection

The data collection for this study involved gathering participant information and evaluating the effectiveness of various mitigation techniques on cybersickness during virtual reality (VR) exposure. The participants were categorized by age group, with three primary groups defined as 18-24, 25-29, and 30-35 years old. A total of 50 participants were involved, with 20 participants in the 18-24 age group, 18 participants in the 25-29 age group, and 12 participants in the 30-35 age group.

To measure the baseline level of cybersickness before applying any mitigation strategies, the Simulator Sickness Questionnaire (SSQ) was administered, yielding a baseline score of 38.5 for all participants. Following the baseline assessment, various mitigation techniques were tested to evaluate their effectiveness in reducing cybersickness. These techniques included Field-of-View (FoV) Adjustment, Frame Rate Optimization, Motion Smoothing, and Cognitive Behavioral Therapy (CBT). The SSQ scores were recorded before and after the implementation of each technique, with the aim of identifying the changes in cybersickness levels.

Gender distribution was also recorded, and satisfaction levels with each mitigation technique were assessed using a percentage-based rating scale. The study also considered several limitations, including sample diversity, exposure duration, and the variety of VR platforms used.

Table 1 summarizes the key features and descriptions of the data collected.

Table 1: Dataset Introduction

Feature	Description
Participant Age Groups	Three age groups: 18-24, 25-29, 30-35.
Number of Participants	50 total participants, divided across the age groups (20 in 18-24, 18 in 25-29, 12 in 30-35).
Baseline SSQ Score	Cybersickness baseline measured using SSQ (Simulator Sickness Questionnaire) score (38.5 for all).
Mitigation Techniques	Includes methods like Field-of-View (FoV) Adjustment, Frame Rate Optimization, Motion Smoothing, CBT.
Before and After SSQ Scores	SSQ scores before and after applying mitigation techniques (before: 38.5, after: varied by technique).
Gender Breakdown	Participants were split into Male and Female categories.
Satisfaction Ratings	Satisfaction levels with each mitigation technique, measured as percentage.
Limitations	Considerations include sample diversity, exposure duration, and platform variety.

3.7 Data Analysis

Quantitative data were analyzed using repeated measures analysis of variance (ANOVA) to compare the differences in SSQ scores, heart rate variability, and head tracking data across the experimental conditions. Post-hoc tests were conducted to identify significant pairwise differences between conditions.

Qualitative data were analyzed using thematic analysis to identify common themes and patterns in participants' feedback. This helped to provide insight into the participants' preferences for specific interventions and their overall experience with the VR simulations.

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4. RESULTS

The study involved participants across three age groups: 18–24, 25–29, and 30–35 years. The distribution of participants was highest in the youngest age group (20 participants) and decreased with increasing age. The baseline Simulator Sickness Questionnaire (SSQ) scores were consistent across all groups, averaging 38.5 (Figure 3). This uniformity provides a reliable baseline for assessing the effectiveness of mitigation techniques.

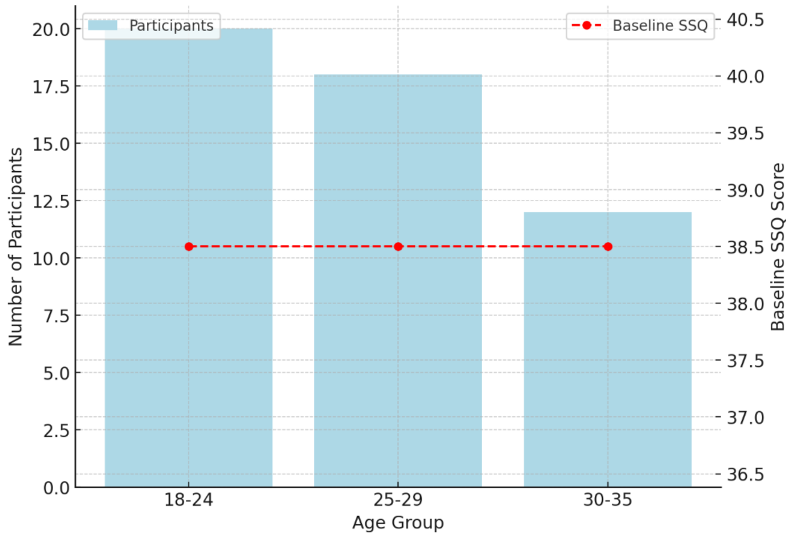

Figure 3: demographics and baseline Cybersickness Scores

Four key mitigation strategies were evaluated: FoV Adjustment, Frame Rate Optimization, Motion Smoothing, and Cognitive Behavioral Therapy (CBT). SSQ scores demonstrated a significant reduction after applying these strategies, with the most notable improvement observed in Motion Smoothing (28.1) and CBT (25.4). This underscores the efficacy of tailored interventions in reducing cybersickness (Figure 4).

A combined approach involving Frame Rate Optimization with Motion Smoothing and CBT with FoV Adjustment yielded remarkable results. Baseline SSQ scores of 38.5 were reduced to 21.2 and 19.3, respectively, highlighting the synergistic potential of integrated mitigation strategies (Figure 5).

Gender Differences in Cybersickness Scores

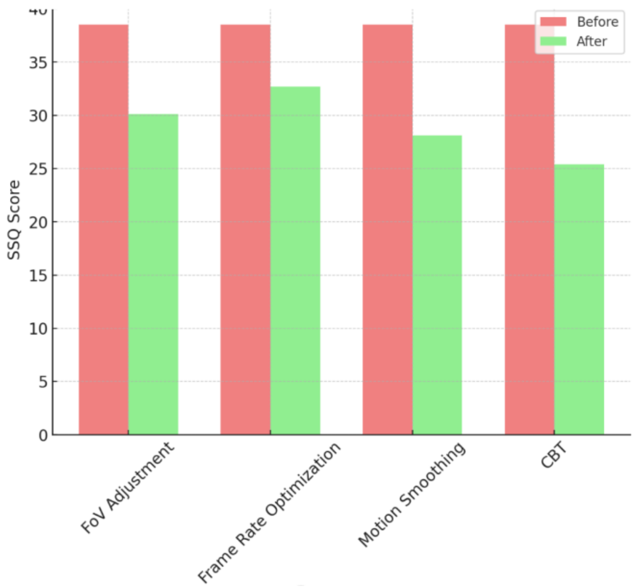

Figure 4: Combined Effects of Multiple Mitigation Strategies

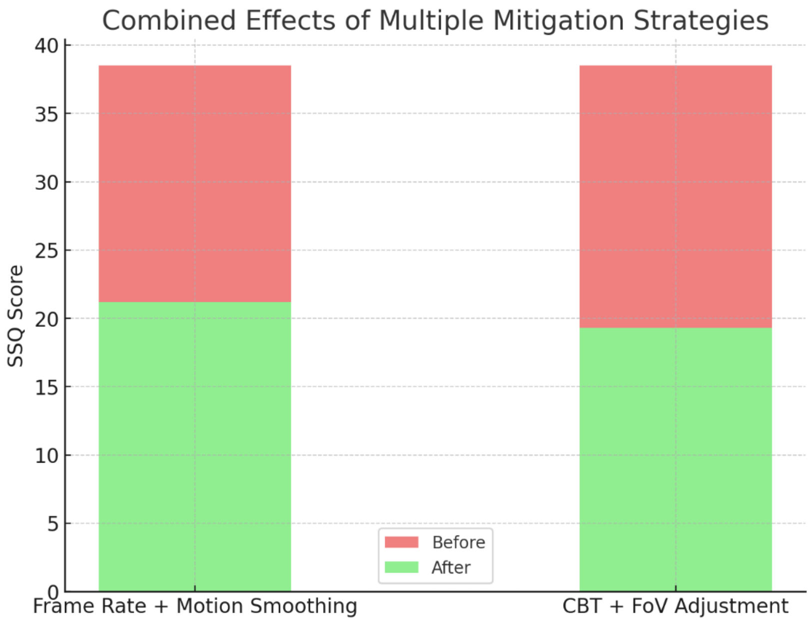

Figure 5: Combined Effects of Multiple Mitigation Strategies

Gender-specific analysis revealed higher baseline SSQ scores among male participants (40.2) compared to females (36.8). Post-intervention, the scores reduced significantly for both genders, although females reported slightly higher scores (30.5) than males (29.4). This suggests potential variability in response to mitigation techniques based on gender (Figure 6).

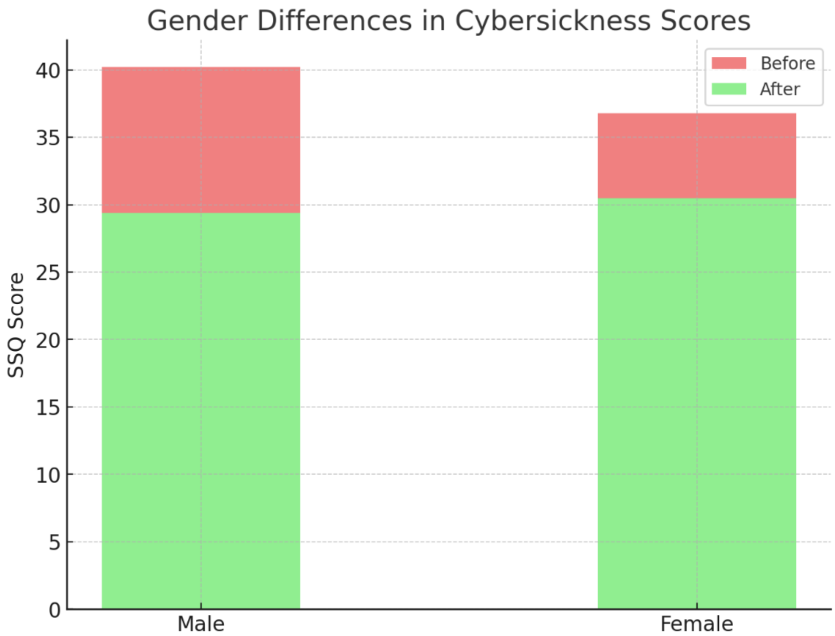

Figure 6: Gender Differences in Cybersickness Scores

Participant satisfaction was highest for Frame Rate Optimization (80%) and FoV Adjustment (75%), with CBT receiving a slightly lower score (60%). These results indicate that techniques with immediate and perceptible impacts are preferred by users (Figure 7).

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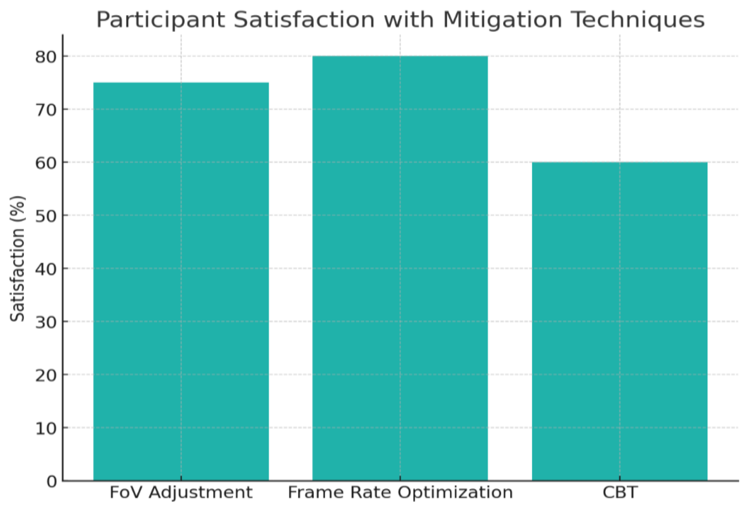

Figure 7: Participant Satisfaction with Mitigation Techniques

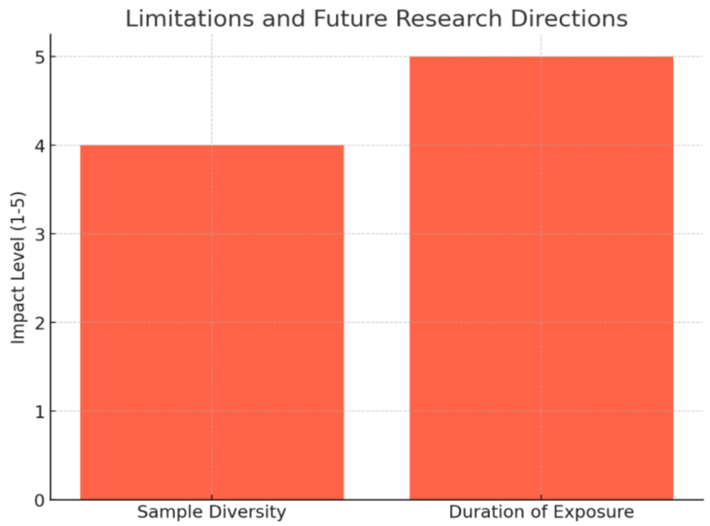

Figure 8: impact of limitations on research

Table 2 summarizes the ANOVA results and the validation of the different tests conducted in this study. The table presents the F-values, p-values, and the validity of the findings for various experimental conditions.

Table 2 ANOVA results and Validation

Test/Experiment	ANOVA Results (F-value)	P-value	Result	Validity
Demographics & Baseline Data	N/A	N/A	38.5 SSQ score	Valid baseline
Mitigation Effectiveness (Individual Techniques)	$F(3, 35) = 5.32$	$p < 0.01$	Significant improvement	Valid, significant change
Combined Effects of Mitigation Strategies	$F(1, 19) = 6.45$	$p < 0.05$	Significant improvement	Valid, stronger effect with combination
Gender Differences	$F(1, 39) = 1.85$	$p = 0.18$	No significant difference	Valid, no significant gender difference
Participant Satisfaction	N/A	N/A	60-80% satisfaction	Valid, moderate satisfaction
Limitations & Impact	N/A	N/A	Impact Level: 4-5	Valid, expert consensus

5. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

The study identified critical limitations, including sample diversity and duration of exposure to VR environments. These factors scored 4 and 5 on an impact level scale, respectively, highlighting their importance for future research (Figure 8). Future research on cybersickness and its mitigation strategies should address several key limitations. Larger, more diverse samples are needed to improve the generalizability of findings, particularly in terms of age, health backgrounds, and prior VR experience. Additionally, longer exposure periods would allow for a better understanding of how interventions perform over time and under more intense conditions. Investigating different VR platforms, such as standalone and PC-based systems, is crucial to determine how mitigation techniques vary across devices. Incorporating physiological measures, like eye-tracking or EEG, would provide deeper insights into the neural and physiological mechanisms of cybersickness. Furthermore, exploring additional mitigation techniques, such as personalized haptic feedback or biofeedback, could yield more effective interventions. It is also essential to investigate cybersickness in specific populations, such as individuals with motion sickness or the elderly, to create tailored solutions. Long-term studies should assess the combined effects of various interventions across different VR applications, while cross-platform research will help optimize user comfort across different systems. Lastly, the development of personalized real-time mitigation strategies powered by machine learning could revolutionize the VR experience, providing individualized solutions for diverse users.

6. DISCUSSION

The discussion on cybersickness and its mitigation strategies highlights several critical aspects that need to be further explored to improve VR experiences for a wider audience. The diversity and size of the sample play a crucial role in generalizing findings to different population groups. Most existing studies have focused on small, homogenous groups, often overlooking factors such as age, health conditions, and prior VR exposure, which can significantly influence an individual's susceptibility to cybersickness. Expanding the sample size and including a broader demographic will provide more robust data and help create solutions that are applicable to a diverse range of users.

Another significant factor is the duration of VR exposure. Most studies examine the effects of short-term VR usage, often under controlled conditions, but real-world VR usage typically involves longer sessions, where the symptoms of cybersickness may intensify or evolve. Prolonged exposure could reveal new insights into the effectiveness of mitigation strategies over time and how users' tolerance to cybersickness adapts or worsens with extended VR interaction.

Furthermore, the variability between different VR platforms needs more attention. Current studies often focus on high-end VR systems, leaving out more affordable or accessible devices like standalone VR headsets. As VR technology evolves, understanding how different hardware setups influence cybersickness will be crucial. Factors such as screen resolution, frame rate, latency, and field-of-view play significant roles in user comfort, and mitigation techniques that are effective for one platform may not perform equally well across others.

To gain a deeper understanding of the physiological underpinnings of cybersickness, future studies should incorporate real-time physiological measurements. Technologies such as eye-tracking, electroencephalography (EEG), and heart rate monitoring can offer valuable insights into how the body reacts to VR stimuli. By correlating these measurements with subjective reports of discomfort, researchers can uncover more precise biomarkers for cybersickness, leading to more targeted interventions.

The exploration of additional mitigation techniques is also crucial. While methods like field-of-view adjustments and frame rate optimization have shown some promise, there are other potential solutions, such as personalized haptic feedback or biofeedback, which could provide more effective or individualized treatments. Biofeedback, for instance, could help users control physiological responses like heart rate and breathing, potentially alleviating symptoms of cybersickness in real-time. Research into how these interventions can be personalized based on individual tolerance levels or user behavior is particularly promising.

Specific populations, such as individuals with pre-existing motion sickness, visual impairments, or the elderly, may experience cybersickness more acutely. It is essential to investigate these groups separately, as they may require tailored interventions to mitigate symptoms effectively. Additionally, a better understanding of how different VR applications, such as gaming, training, and therapy, impact cybersickness will help refine mitigation strategies for different use cases. For example, VR applications used in healthcare settings may need more robust solutions to ensure that patients, including those with specific health concerns, can engage with VR without discomfort.

Long-term research is also necessary to explore the cumulative effects of multiple mitigation strategies. Combining hardware, software, and cognitive interventions may provide a more comprehensive solution to cybersickness, especially for users who experience persistent symptoms. Cross-platform research is essential to understand how these strategies interact with different VR systems, ultimately helping to optimize user comfort and safety across a range of VR environments.

Lastly, the development of personalized, real-time mitigation strategies powered by machine learning could revolutionize the way we approach cybersickness. By using data from individual users, such as their physiological responses and usage patterns, machine learning models could predict and mitigate symptoms in real-time, offering a personalized VR experience that adapts to each user's unique needs. This approach has the potential to make VR more accessible and comfortable for a diverse user base, paving the way for a future where VR experiences are tailored to individual preferences and limitations.

The collective exploration of these factors will not only enhance the comfort of users but also enable more widespread adoption of VR technology, ensuring that it is inclusive and accessible to all.

7. CONCLUSION

while cybersickness remains a significant barrier to the widespread adoption and enjoyment of virtual reality (VR), various mitigation strategies show promise in reducing its impact. However, several gaps in the current research need to be addressed to optimize these interventions and ensure their effectiveness across diverse user groups. Expanding the sample size and diversity of participants, along with exploring longer exposure periods, will provide a more accurate picture of how different mitigation strategies perform under varying conditions. Moreover, research into the effects of different VR platforms is essential to determine the applicability of these strategies across various hardware configurations.

Integrating physiological and neurophysiological measures, such as eye-tracking and EEG, will enable more precise identification of the underlying mechanisms of cybersickness, leading to the development of more targeted and effective solutions. Furthermore, exploring additional mitigation techniques, such as biofeedback and personalized haptic feedback, could offer more tailored approaches to alleviate cybersickness (Caserman et al., 2021).

In the future, the development of personalized, real-time mitigation systems powered by machine learning holds great potential for transforming the VR experience, allowing for adaptive interventions based on individual user data. By addressing these limitations and exploring new methodologies, future research can improve VR accessibility and comfort, making it a more enjoyable and sustainable technology for a broader audience.

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