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A study on the discomfort of virtual reality glasses: A systematic review

Um estudo sobre o desconforto dos óculos de realidade virtual como: Uma revisão sistemática

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ABSTRACT

The objective of this article is to present a systematic review of the literature on technological innovations regarding the use of Virtual Reality glasses and possible discomfort. From the concepts such as "cognitive*sickness*" and "*motion sickness*", we will have a starting point to deepen our knowledge about the effects, such as nausea, headaches, among others, when using virtual reality glasses. The methodology employed in this systematic review and bibliometric analysis focused on the discomfort associated with the use of virtual reality (VR) glasses. The research adopted a quantitative analysis of the data and information available on the subject, aiming to understand the effects such as nausea, headaches, among others, when using VR glasses. The results obtained in the review addressed several aspects of VR use, including the promise of immersive VR being safe and effective for application in the elderly, with no significant records of symptoms of sham disease. The research highlighted the importance of understanding the needs and satisfaction of users in the process of designing and implementing VR solutions, highlighting how VR can play a significant role in varied contexts, from pre-occupancy assessment in older adults to training and reducing motion sickness symptoms using VR technologies. In addition, it was investigated whether individual characteristics of balance and tendency to motion sickness are related to vulnerability to cybernetic disease, a side effect caused using virtual reality with head-mounted displays. In summary, this systematic review contributed to the understanding of the discomfort associated with the use of VR glasses, exploring strategies to minimize adverse effects and improve the user experience, with the aim of increasing the adoption of this technology in several areas.

Keywords: Augmented Reality, Virtual Reality, *Cybersickness*, *Motion Sickness*.

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INTRODUCTION

Virtual Reality (VR) and Augmented Reality (AR) have aroused growing interest in the scientific and commercial community due to their ability to provide immersive and interactive experiences to users. However, prolonged use of virtual reality glasses can cause discomfort and dizziness in some people, which can negatively impact the user experience and limit the adoption of this technology in a variety of contexts. These side effects, according to CHUL CHUN, et al. (2023), known as "*cybersickness*" or "*simulator sickness*," are similar to motion sickness symptoms experienced while traveling by car, plane, or boat. It is critical to understand the side effects associated with long-term use of immersive technologies, such as virtual reality, and to develop strategies to minimize them. This not only improves the user experience but also increases the adoption of these technologies in different fields such as gaming, entertainment, education, and training. By overcoming the challenges related to discomfort and dizziness, we will be able to explore the full potential of these technologies and open up new possibilities for interaction and immersion for users.

The sections of this article are organized into Introduction, which presents the growing interest in Virtual Reality (VR) and Augmented Reality (AR), discussing side effects such as *"cybersickness*" and the importance of developing strategies to minimize these discomforts to improve the user experience and facilitate the adoption of these technologies; Theoretical Framework that explains fundamental concepts about VR and AR, the technology behind them, and how these innovations are being applied in various fields, such as gaming, military training, and healthcare. It also discusses the potential of these technologies to transform digital interaction and their benefits in specific areas; Methodology**:** describes the process of systematic literature review and bibliometric analysis used to compile and analyze data on discomfort associated with the use of VR glasses, including the selection of articles, inclusion and exclusion criteria, and approaches to data analysis; Analysis and Discussion of Results**:** presents the results obtained from the review, highlighting the main findings on the effects of prolonged use of VR goggles, such as *cybersickness*, and discusses the strategies suggested by the literature to mitigate these adverse effects; Final Thoughts**:** summarizes the main findings of the review, emphasizing the importance of understanding and mitigating the discomfort caused by the use of VR goggles in order to broaden their adoption. The Systematic Review also highlights the need for more research to fully explore the potential of VR and AR in different areas; References**:** lists all the bibliographic sources consulted for the preparation of the systematic review, providing a

comprehensive resource for readers interested in exploring more deeply any of the topics discussed.

The research aims to verify the possibility of discomfort when using VR glasses, applying a questionnaire to a certain number of people to evaluate the results in order to improve the user experience and increase the adoption of the technology in different areas. This is essential to explore the full potential of VR and open up new possibilities for interaction and immersion for users, significantly transforming areas such as healthcare, education, and entertainment. This study aims to deeply analyze the causes and effects of virtual reality-induced motion sickness by applying a comprehensive questionnaire to individuals of varying demographic profiles, including age, gender, and prior experience with virtual reality technologies. The meticulous collection and analysis of data has the purpose of identifying specific patterns of discomfort and the conditions under which they occur, allowing not only the elaboration of recommendations to mitigate such effects, but also the improvement of the design of immersive experiences. This study is part of a context of rapid technological evolution and growing adoption of virtual environments, standing out for its significant contribution to the field of human-computer interaction, guiding developers, designers and researchers in the creation of more comfortable and engaging solutions for users.

THEORETICAL REFERENCE

Virtual reality (VR) and augmented reality (AR) have shown promise in a variety of areas, including education, healthcare, and entertainment, due to their ability to provide immersive and interactive experiences. However, the adoption of these technologies still faces challenges related to the discomfort and dizziness that some users experience, known as "*cybersickness*".

According to Mahmood et al. (2018), virtual reality is a technology that creates realistic and multisensory virtual environments, allowing the user to interact with the virtual environment and promoting physical changes in it. This technology has been widely used in areas such as gaming, military training, and healthcare. In the context of health, Tseng and Giau (2021) highlighted the potential of immersive VR as promising and safe for application in the elderly, with no significant records of "*simulator sickness*" symptoms. This indicates the importance of understanding the needs and satisfaction of users in the process of designing and implementing VR solutions, emphasizing how VR can play a significant role in varied contexts. In addition, Chul Chun et al. (2023) associated the side effects of VR, such as cybersickness, with symptoms

of motion sickness, suggesting the need to further investigate the conditions under which this syndrome develops to improve the user experience and facilitate the adoption of the technology. Another relevant research is that of Kourtesis et al. (2022), who developed two versions of the VR Cyber Illness Questionnaire (CSQ-VR) to assess validity and comparison with the "*Simulator Sickness Questionnaire*" (SSQ) and the "*Virtual Reality Sickness Questionnaire*" (VRSQ). This study provides a useful tool for measuring and understanding *cybersickness* in VR environments.

THE USE OF VIRTUAL REALITY GLASSES AND "CYBERSICKNESS" OR "*MOTION SICKNESS"*

The use of virtual reality (VR) glasses has gained increasing popularity in recent years, providing users with an immersive experience in virtual environments. However, one issue that many people face when using this technology is the feeling of discomfort known as "cybersickness" or "motion sickness".

Cybersickness is a condition similar to motion sickness that some people experience when utilizing virtual reality devices such as VR glasses. This sensation occurs when there is a discrepancy between the movements that the wearer perceives through the glasses and the physical movements that he performs in the real world, this can trigger a response of motion sickness and discomfort.

The main causes of cybersickness are related to the way the brain processes sensory information. During the use of virtual reality glasses, the brain receives visual signals that indicate movement, but the vestibular system, which is responsible for balance and spatial perception, does not detect the same movements. This discrepancy between the senses can lead to "*cybersickness*."

In addition, factors such as latency of VR devices, low resolution of images, rapid movements, and spatial disorientation can also contribute to the emergence of *cybersickness*. Each person reacts differently and the intensity of motion sickness can range from mild to disabling depending on the individual and the type of virtual reality experience.

To minimize cybersickness, developers of virtual reality technology are working on continuous improvements. This includes reducing the latency of VR devices, improving the quality of images, and implementing more accurate motion tracking techniques. These improvements help reduce sensory discrepancy and, consequently, the occurrence of motion sickness.

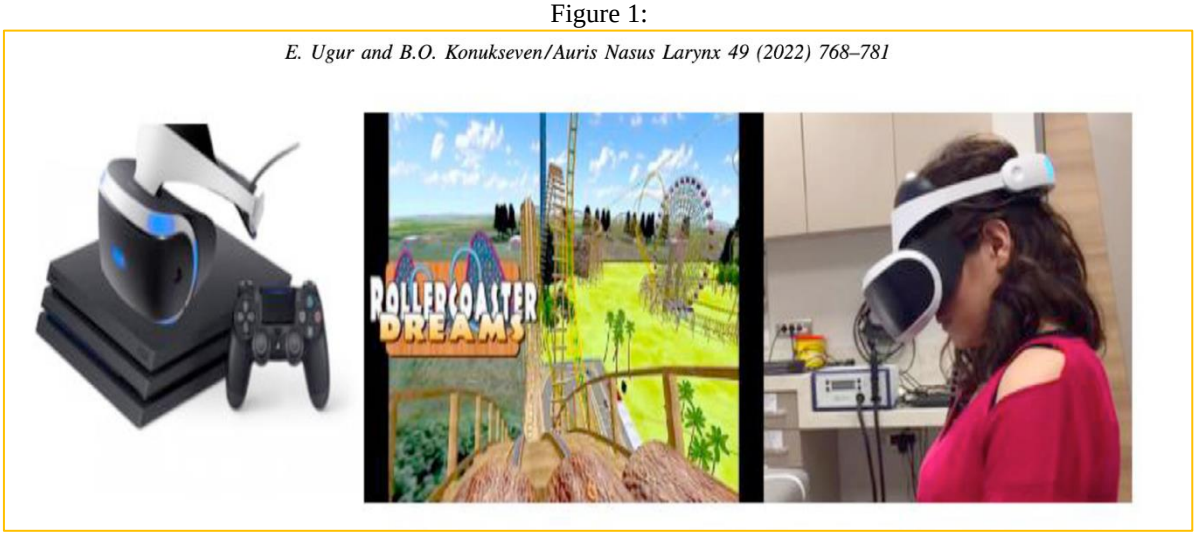
According to KOACH, et al (2018), there is a new phenomenon of "*motion sickness*", in which playing complex video games on large screens or using virtual reality (VR) headsets can lead to symptoms strikingly similar to those of classic motion sickness, even if the affected people are not physically moving. As early as 1994, in a study of 146 volunteers, 61% of the probands developed symptoms of malaise during a 20-minute VR immersion period. Young people, especially children aged 6 to 12, and women are thought to be more susceptible to motion sickness, which means that symptoms induced by computer simulations are particularly significant for this group. Whatever the scenario that leads to motion sickness, it is often necessary for the affected person to perform active control tasks in fast-moving scenarios or on the screen. Examples of this are the driver who has to intervene in a self-driving car, the drone pilot in a complex situation or the operator of a virtual reality operating system. In order to ensure that these control tasks are carried out safely, the critical questions are whether and when relevant reductions in alertness and competence occur, and whether these are noticed before nausea symptoms subside in a generalized manner.

Another study, such as that of SALIMI and FERGUSON-PELL, (2021), investigated the effect of Virtual Reality (VR) training on the reduction of visually induced motion sickness (VIMS) in 14 healthy participants. Up to four training sessions were conducted, and the results were evaluated through explicit statements by the participants and the Motion Sickness Assessment Questionnaire (MSAQ). It was observed that total, gastrointestinal and central motion sickness decreased significantly over the course of the training sessions. After adjusting to motion sickness, participants performed agility tests in VR and in the real world, assessing their level of motion sickness and virtual presence. The results showed that the VR systems tested generated little motion sickness and high virtual presence scores, with no statistically significant differences between them. In addition, virtual presence has been shown to be negatively correlated with VIMS. These results indicate that VR training can help reduce motion sickness and improve the user experience in VR environments.

According to UGUR and KONUKSEVEN, (2022), motion sickness is triggered by incompatibilities in visual-vestibular autonomic pathways, even in individuals with healthy vestibular, visual, and somatosensory structures. Virtual Reality (VR) technology can be used for rehabilitation purposes, allowing interactions in virtual environments that simulate real life. These systems can monitor motion kinematics and simulate tactile sensations. However, people with sensitivity to motion sickness can be easily triggered by indirect stimuli in VR applications. In vestibular rehabilitation, the stimuli that trigger symptoms can also be used to increase

adaptation skills. Thus, VR systems can help in adapting to situations of visual-vestibular incompatibility, providing gradual exposure to specific stimuli. The healthy VOR (vestibulo-ocular reflex) arc is an essential component of the balance system and is necessary for continuous stimulation during head movements and reorganization of the visual angle.

Figure 1:



Fonte: Ugur e Konukseven, (2022).

According to KIM, et al, (2018), who investigated the side effects of Virtual Reality (VR) devices, such as simulators, with a focus on motion sickness. The simulator disease questionnaire (SSQ), traditionally used to measure motion sickness in simulators, was used. Twenty-four users performed target selection tasks in a VR environment, with the SSQ administered immediately after each task. The SSQ was revised to develop a specific questionnaire for RV disease, which serves as a measurement index in this setting. In addition, it has been observed that the target selection method and button size are significant factors affecting motion sickness in a VR environment. The results of this study can be used to measure and project simulator disease when using VR devices in future studies.

Motion sickness, according to CHUL CHUN, et al, (2023), also known as "motion sickness", is a syndrome mainly characterized by nausea and motion sickness caused by sensory conflict. The prevalence of motion sickness is high in the population, especially among women, but the neural mechanisms responsible for it are not yet fully understood. With the growth of technology, motion sickness also occurs in virtual environments, such as simulators and virtual reality experiences, and is known as "*cybersickness*" or "*virtual reality sickness"*. Motion sickness is an obstacle to immersion in virtual environments, and understanding its developmental conditions is essential to offering good virtual reality services. Motion sickness

provocation models, such as labyrinthine stimulation and the use of rotating chairs, have been used to study the disease and develop therapies; The objective of this study was to compare the symptoms of motion sickness caused by virtual reality stimuli in volunteers with and without a history of the disease, as well as to investigate the influence of different visual stimuli on the generation of symptoms.

Another study, conducted by PÕHLMANN, O'HARE, and FÕCKER (2021), point out that gender and experience in virtual games can affect VR disease induced by apparent movement stimuli. Women experienced significantly more VR disease in this study compared to men and rated their susceptibility to motion sickness higher compared to men. Neither sex nor previous video game experience had an effect on the magnitude of the head movements elicited by the participants over the course of the experiment. The movement signals perceived by the illusions in this study may not have been strong enough to elicit head movements related to the visual stimulus. In addition, the previous gaming experience seemed to have a positive adaptive effect on women, but the opposite effect on men. This interaction between gender and player type would suggest that several additional factors could also influence the experience of VR sickness, such as the type of virtual environment that is presented. This makes it difficult to decide on how best to design a virtual environment to make it accessible to everyone. Training individuals first, using disease-inducing environments without disease, before immersing them in a complex virtual environment in VR can be an effective method in reducing adverse symptoms. However, a less time-consuming method for the user would be the option of different settings within VR games, allowing the player to choose a less disease-inducing option in the game, for example by reducing the speed at which the game is played. In addition, optimized illusions are recommended as stimuli for the investigation of VR disease caused by conflicts between sensory systems, since they minimize some conflicts for its accommodation.

According to ZHANG, (2020), in his research, the secondary effects of using virtual reality (VR) headsets in games were investigated by analyzing different frame rates per second (FPS), refresh rates, and scene scenarios. Common symptoms reported by participants included general discomfort, headache, stomach pain, nausea, sweating, tiredness, and disorientation. The results indicated that low FPS, low refresh rates, and realistic images increased the likelihood of discomfort in players. Fighting and shooting games have also been identified as likely to cause discomfort. When VR headsets project images in front of the eyes, the user's brain creates a complete immersion in virtual reality. However, the visual movements of the scenes can induce motion sickness and a sense of movement.

Improper use of VR headsets can lead to serious problems such as loss of real-world awareness, motion sickness, dizziness, nausea, headaches, seizures, trips, falls, discomfort, and repetitive stress injuries. These problems are known as "cybersickness" or simulator sickness. The conflict between sensory stimuli is one of the main causes of this condition and the refresh rate of the display device is a major technical factor for motion sickness, as low refresh rates can result in choppy images and trigger motion sickness. VR manufacturers have been striving to improve this aspect by increasing the refresh rates of headsets to minimize adverse symptoms.

While many studies have investigated the causes of motion sickness in VR, few have looked at individual reactions to motion sickness based on user experience. In this regard, the study conducted a questionnaire to investigate adverse symptoms in different games, FPS, refresh rates, and scenarios, as well as discuss possible improvements in VR devices and games. It can be seen that the use of virtual reality headsets for gaming can lead to different reactions in different people. The study identified that low FPS, low refresh rates, and realistic images can increase discomfort and the research conducted highlighted the importance of improving the user experience through technical advancements in VR devices and games.

In the study presented by GEMERT and BERSTROM (2022), despite decades of research on motion sickness in virtual reality (VR), it is exposed that there is still no clear understanding of how these differences can be explained. Several factors related to software, demographics, and hardware have been identified as influences on susceptibility to VR disease. When designing a VR locomotion technique, it is important to consider the potential risks of VR disease, and during the evaluation of the technique, it is critical to clearly identify which aspects need to be improved.

While a lot of research has been done on motion sickness in VR, there is still no consensus on its exact causes. It's crucial to consider a variety of factors, such as software, demographics, and hardware, when designing and evaluating VR techniques. In-depth understanding of these aspects is necessary to improve the user experience and reduce the risks of VR sickness.

According to NOH, PARK, and KIM (2022), The main cause of motion sickness, also known as motion sickness, is the sensory mismatch between visual and vestibular stimulation. When there is inconsistency in sensory information, such as in the example of being inside a ship's cabin where relative motion is not visible, motion sickness can occur. Even on an open deck, seasickness can still be significant due to the lack of correspondence between visual feedback, such as the movement of ocean waves.

Cybernetic disease, or simulator disease, is similar to motion sickness, but it occurs when using a motion simulator instead of an actual moving vehicle. In this case, it is also caused by sensory mismatch, but in reverse. The user's body is usually stationary, but visual feedback features dynamic components, such as those found on roller coasters.

Both motion sickness and cybernetic disease are caused by the sensory mismatch between visual and vestibular stimulation. Motion sickness occurs when there is an inconsistency between these sensory stimuli, and can be intensified in situations where relative motion is not visible. Understanding these causes is important to mitigate these adverse effects when designing virtual reality experiences and motion simulators.

Other research by LAESSOE, et al, (2023), examined the side effects of using head-mounted viewing devices (HMD) in virtual reality (VR), known as "cybersickness." The aim was to explore individual balance characteristics and self-reported tendency to motion sickness that could be related to vulnerability to cybersickness. A total of 45 healthy youngsters were selected, who were exposed to an application of VR with HMD for four minutes, remaining standing without support. Balance characteristics were measured before (sensory orientation test) and during (balance platform) exposure to VR. Symptoms of cybersickness were recorded using the simulator motion sickness questionnaire (SSQ). Data were analyzed considering subgroups with and without motion sickness tendency.

The results showed that participants were negatively affected by VR exposure, with a significant increase in "cybersickness" symptoms as measured by SSQ. The majority of participants (73%) reported increased discomfort. Nausea and disorientation scores on the SSQ were affected, but not the oculomotor disturbance score. Surprisingly, participants reported discomfort already after the initial balance assessment on the sensory orientation test. Participants with a self-reported tendency to motion sickness were more affected by this challenge to sensory integration. Increased postural instability was observed during exposure to VR, but there was considerable individual variance in postural response.

However, the study did not identify individual balance characteristics that could be associated with vulnerability to *cybersickness*. In addition, it was found that the adverse effect of the sensory orientation test became a bias, reducing subgroup differences in vulnerability to *cybersickness*.

"*Cybersickness*," according to KYOUNG-MI, et al, (2022), refers to the uncomfortable side effects, such as headaches, dizziness, and nausea, experienced when experiencing virtual reality (VR). The research investigated "*cybersickness*" in people with sensitivity to motion

sickness using electroencephalography (EEG), the Simulator Motion Sickness Questionnaire (SSQ), and simple VR content. Based on the Movement Disorder Susceptibility Questionnaire (MSSQ) scores, 40 men in their twenties were selected as the sensitive group, 20 men, and the non-sensitive group of 20 men. The experiment contained two conditions: a baseline condition that represented a resting state, and a "cyber sensitivity" condition in which watching VR content induced that sensitivity. The SSQ score increased significantly after watching VR content in both groups. The sensitive group had significantly lower absolute potency in the beta and gamma bands than the non-sensitive group. The sensitivity condition showed significant increase in delta and decrease in alpha compared to the baseline condition.

Another study on the "*cybersicness*", carried out by ALIREZA, et al (2018), exposes that existing evidence suggests that the "*cybersicness*" may be clinically different from "classical" motion-induced motion sickness; However, this evidence was obtained in separate studies that focused on only one of the two conditions. The aim of this study was to directly compare the subjective symptoms and physiological effects of motion sickness induced by physical movement and the use of virtual reality (VR) in the same individuals. Two stimulation methods were used: cross-coupling of "*Coriolis"* which is a physical movement and an amusement park (VR) ride, with 30 healthy volunteers being exposed to the two stimuli on separate days.

During the exposures, nausea scores were recorded, and after the experiments, participants completed the motion sickness assessment questionnaire (MSAQ) to assess subjective symptoms. In addition, tonic and phasic levels of forehead skin conductance (SCL) were measured before and during exposure in both methods.

The results showed that nausea onset times and maximum nausea ratings were significantly correlated during both provocations. The symptom profile assessed by the MSAQ revealed substantial correlations between the total symptom scores and between the different symptom clusters, as well as between individual symptoms assessed in both conditions. Both provocations resulted in increased tonic level of SCL associated with nausea, with a close correlation between the conditions. In addition, there was a significant increase in the amplitude of phasic skin conductance transients in both experiments.

Based on these results, presented by ALIREZA, et al (2018), it can be observed that the symptoms and physiological changes that occur during the "*cyber*Motion sickness and classic motion sickness are quite similar, at least in the advanced stages of these conditions. This indicates that the two conditions may share similar mechanisms of triggering and manifesting symptoms.

Also, in another research, carried out by KIM, et al (2020), in which it addresses the cybernetic disease, known as visually induced motion sickness (VIMS), which occurs in virtual reality (VR) environments due to the body imbalance caused by self-generated movement. The main objective was to estimate the VIMS score in relation to the content and to calculate its temporal sensitivity. To this end, we propose an architecture composed of two consecutive networks: one to mimic the neurological mechanism of motion sickness and the other to express spatial and temporal characteristics in the generated frames. The trained model can calculate the sensitivity of the VIMS for each frame of the VR content using weakly supervised approach. In addition, a large database of VR content is launched. In the experiments, the proposed framework shows excellent performance in predicting the VIMS score compared to existing methods, including deep learning-based approaches. A way to visualize the cognitive response to visual stimuli and demonstrate disease activation in a similar way to clinical studies is also proposed.

Due to the rapid growth in Virtual Reality (VR) technology, according to CHATTHA, et al (2020), the VR industry is expected to grow by around 26.89 billion by 2022. However, with its extensive growth and immersive inclusion in human life, health-related issues are reported, including but not limited to feeling nauseous, vomiting, dizziness, and cold sweat. These issues introduce a well-known side effect called motion sickness to VR users. Consequently, motion sickness limits the VR community in fully adapting this immersive technology.

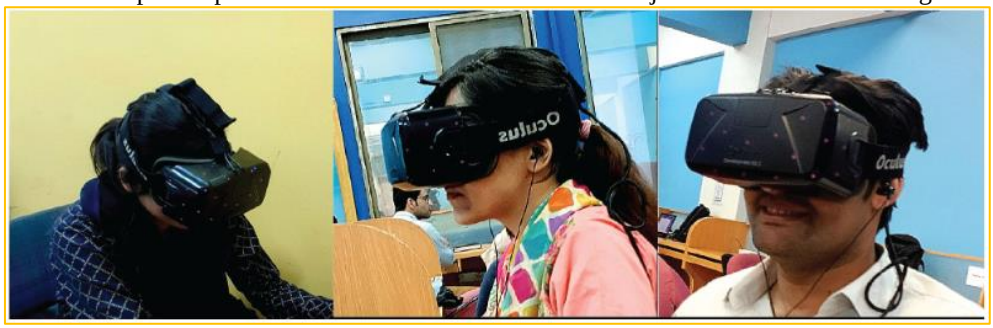
Figure 2: An image of the pleasant genre virtual environment

Fonte: Chattha, et al (2020).

Figure 3: An image of the virtual environment of the horror genre

Fonte: Chattha, et al (2020).

Figure 4: Participant experiences the virtual environment and objective measures are being recorded



Fonte: Chattha, et al (2020).

Since there is no shortage of literature investigating motion sickness caused by VR, still, research on the effect of VR on human physiology is still in its infancy. This research presents new findings by comparing different factors such as gender, motion sickness experience, 3D gaming experience, and VR experience. In addition, it reports the impact of factors in a design within the subjects under different genres of virtual environment. Key findings report that there is a significant difference in the amount of motion sickness when switching from the enjoyable genre to the ambient horror genre and having a strong genre dependency. In addition, the type of virtual environment is an essential factor that has a noticeable effect on the user's blood pressure, blood sugar, and heart rate. However, past experiences with motion sickness and 3D gaming show no significant impact on the user's level of motion sickness.

PARK, YUN and KIM (2023), also expose that simulation disease is a significant challenge in the popularization of virtual reality (VR), with the sensory mismatch between the visual and vestibular senses being the main cause of this problem. The use of a resting frame, called a "*Rest*", has been shown to be effective in relieving symptoms. The virtual nose has long been a popular option as a frame"*Rest*", but it can distract from the main content. The study

proposes the use of a motion singularity region (MSP/R), which is the area of the screen with the least amount of movement in navigation content, as a rest board. It is believed that visualizing this region will reduce sensory conflict and disease symptoms. This region can be identified by analyzing the content in relation to motion and estimating the regions with the lowest optical flow. The VR disease reduction effect of looking at MSP/R has been experimentally validated compared to the virtual nose. In addition, MSP/R has been found to be compatible with the user's natural viewing direction, making it less distracting to the main content. Therefore, MSP/R is a practical and viable option as a resting frame to reduce symptoms of VR sickness.

"Cybersicness" occurs in the most diverse forms of interaction with virtual reality, as exposed by WOJCIECHOWSKI, WOJTOWICZ (2022), the phenomenon known as "cybersickness", also referred to as simulation disease, manifests itself in users of virtual reality technologies, as is the case of drone pilots who operate through first-person view (FPV). WOJCIECHOWSKI AND WOJTOWICZ (2022) explore how this problem, which presents with symptoms similar to those of motion sickness — including dizziness, nausea, spatial disorientation, and difficulty concentrating — has become a growing concern with the increased use of drones. The symptoms of simulation sickness are caused by the discrepancy between the visual and vestibular information perceived by the user, leading to a sensory conflict that results in discomfort. Interestingly, studies indicate a variable susceptibility to these symptoms among civilian and military FPV drone users, with about 80% of civilians experiencing dizziness, suggesting that resistance to simulation sickness may be a criterion in the selection of drone pilots. The text also highlights that motion sickness and sham disease share symptoms but differ in their causes and main features, such as the gastrointestinal symptoms prevalent in motion sickness in contrast to the ocular symptoms in sham disease. Factors such as lack of sleep, illness, and stress can increase susceptibility to illness, underscoring the complexity of interactions between visual stimuli, perception, and physical reactions in virtual environments.

OKUNO, SHIMIZU (2022), introduce an innovative approach to mitigating virtual reality (VR) disease, which is often experienced by users of head-mounted viewing devices (HMD). Its method consists of applying a selective blur to the images presented on the HMD, adjusting the level of blur based on the local movement within the user's field of vision, as well as taking into account the user's point of view to preserve the quality and richness of the images. Research has highlighted the effectiveness of peripheral vision blurring, in contrast to central blurring, which may not always be beneficial and can sometimes even cause discomfort. By

implementing this selective blurring method, the authors were able to significantly reduce the symptoms of VR disease while maintaining a rich and immersive visual experience for the user.

Another study by SZPAK, et al, (2022), is the first to directly compare the impact of breaks on virtual reality (VR) illness, perceived workload, reaction time, and learning. The findings do not support the hypothesis that short breaks can mitigate the sequelae of prolonged exposure to VR. Longer breaks, of 40 minutes, are sufficient to reduce the side effects of long continuous exposures without breaks, as well as the sequelae resulting from repeated exposures. Participants reported that repeated pauses affected their perceived performance during VR compared to longer continuous exposures. More research is needed to investigate different pause durations in reducing sequelae and optimizing training schedules. Promoting breaks may not work for everyone and may even have performance drawbacks and increase the logistical costs of training. This should be considered when implementing VR training schedules.

Also, according to ANG and QUARLES (2022), the "*cybersickness*", or visually induced motion sickness, is a significant obstacle to the wider adoption of virtualization technologies. This study investigated how different types of virtual terrain affect cyber sickness in VR. Participants navigated a virtual forest environment with three terrain variants: flat surface, rain with regular bumps, and uneven terrain generated by Perlin noise. The results indicate that users experienced higher levels of "*cybersickness"* in the presence of regular bumps and uneven terrain than when traversing flat geometry. Designers should exercise caution when incorporating uneven terrain into their virtual experiences and maintain awareness of the risks brought about by these design decisions.

Another article published by AL-ASHWAL, et al, (2021), discusses the disease of virtual reality "*cybersickness*", which occurs during exposure to virtual environments and can cause motion sickness-like symptoms, including nausea and dizziness. These adverse effects can negatively affect the use of VR and contribute to increased dropout rates. The aim of the aforementioned study is to objectively and subjectively detect and quantify MS using a helicopter simulator, as well as to investigate the change in self-reported scores under different climatic conditions. The Disease Questionnaire Simulator (SSQ) was used for the subjective score, and the Galvanic Skin Response (GER) was analyzed as a physiological data. The results showed a significant increase in the total SSQ score in stormy conditions compared to clear ones, and a positive but not significant correlation between the change in SSQ score and the amount of GER.

Virtual reality (VR) content, according to KUO, et al, (2021), provides an immersive experience that cannot be achieved through 2D flat panel viewing alone. However, a proportion of people may experience symptoms such as dizziness, headache, and nausea after exposure to VR. Various signal-based physiological methods, such as, have been used to predict the extent of RV disease. However, these methods face challenges, such as sensitivity to noise and reliance on particular devices. Therefore, assessing the degree of VR disease through VR content analysis is an attractive approach. A recent method proposes the use of optical flow to predict the degree of VR disease when viewing 360-degree videos. A new dataset was collected for each sample acquisition, in which the user responds to the Discomfort Score every minute and the Simulator Questionnaire"*Sickness*" (SSQ) at the end of the test. The dataset contains 20 5-minute 360-degree videos, categorized into four different levels of movement. The proposed prediction method considers hybrid temporal characteristics derived from optical flow, including horizontal motion, vertical motion, and "*Drinking Alcohol*".

According to KIM, et al, (2022), there is a lack of definitive research results to allow the creation of methods to predict or optimize the "*trade-offs*" between VR sickness and a sense of presence in immersive VR experiences. To help fill this gap, a large database dedicated to VR disease/presence (VR-SP) is built containing 100 VR videos with associated human subjective ratings. Using this new feature, a statistical model of spatiotemporal and rotational frame difference maps is developed to predict VR disease. An exceptional motion feature is also designed to capture the sense of presence. The aggregate RV-SP model is able to predict RV disease with an accuracy of 90% and the presence of RV with an accuracy of 75%.

According to LIÃO, et al (2020), despite the many improvements proposed to improve the capabilities of VR headsets, one problem that has not disappeared is motion sickness. Motion sickness on VR systems can occur after playing the game for as little as 17 minutes. The development of the Electroencephalogram (EEG) makes it possible to measure various effects of VR. Using an EEG, the system can actively measure the user's cognitive state, unlike the Brain-Computer Interface (BCI), which is commonly used to measure cognitive status. The use of EEG with VR makes it possible to study language processing in a naturalistic environment. The learning process takes place by offering appropriate and inappropriate words based on the visual context. In the field of emotion detection, EEG can be used to assess emotion regulation strategies during VR exposure. EEG in deep learning has been applied in many fields.

There are three prevalent theories that seek to explain the cause of cybernetic illness according to VENKATAKRISHNAN, et al (2020), such as the "Sensory Conflict Theory" which

attempts to explain cybernetic illness in terms of sensory mismatch, the "Poison Theory" which relates the symptoms experienced to those exhibited when the body is poisoned, and the "Postural Instability Theory" which explains cybernetic illness as a consequence of the body's failure to maintain postural stability while experimenting with new stimuli.

Although the exact cause of cyber sickness is unknown, measurement, reduction, influencing factors, etc. have been widely studied and discussed in the context of immersive virtual environments (IVE's). Many factors that influence cyber illness, control over movement is one that deserves attention due to the rise of travel-based VR applications.

In the same vein, RAHIMI, BANIGAN and RAGAN (2020), presented a research that discusses the importance of facilitating simple and easy-to-use techniques for traveling and viewing in virtual reality (VR). The article explains that while realistic interaction techniques are generally preferred, less realistic types of interaction may be beneficial in some cases. The article then discusses techniques for showing visual transitions between two viewpoints in VR, which can affect the viewer's comfort and spatial awareness. The article describes an experiment conducted to compare different variations of these techniques and collect empirical data on their trade-offs.

Three techniques were evaluated: teleportation, animated interpolation, and pulsed interpolation. Based on the results of the study, the authors selected the best variations for each technique. In four experiments with scene transitions in Virtual Reality (VR) with "*Head-Mounted Displays*" (HMDs) tracked, it was found that scene changes with rotation transitions using teleportation are more easily tracked by participants. Changes in point of view involving translation and rotation were more difficult to track than any individual type of change. Animated interpolations allowed a better spatial understanding of the three techniques tested, but were considered worse in terms of disease. It is recommended to use a combination of different techniques based on the scene and the viewer's point of view. Results are limited to a limited number of variations of transition techniques and environments, and other interacting and environmental factors are important.

The authors YEO, KWON, and PARK (2022), presented a study that investigated the effect of sound and motion synchronization on the reduction of visually induced motion sickness (VIMS) during the virtual reality (VR) experience. 25 participants were divided into four groups and cycled for 5 minutes in a "*headmounted display*" with different types of sound and motion presentations. The results showed that participants who experienced sound and movement synchronization had significantly lower VIMS scores, as measured by the rapid motion sickness

scale and simulator illness questionnaire, compared to the other groups. In addition, EEG signal analysis revealed that the simultaneous presentation of sound and motion led to a significant increase in alpha waves in the parietal and occipital lobes. Therefore, it was possible to conclude that sound and motion synchronization is effective in reducing VIMS during the simulated cycling experience in a VR environment.

Even in the medical field, according to KIM, et al (2021), the use of virtual reality (VR) in the treatment of psychiatric disorders is increasing. However, cybersickness, a set of symptoms similar to motion sickness, has been a challenge. In this study, we investigated the clinical factors affecting cyber illness during the application of VR in highly stressed people. We recruited 83 healthy adult participants with a high level of stress and performed psychiatric, ophthalmological, and otological evaluations and extracted physiological parameters. Participants were divided into two groups, exposed to VR videos with varying degrees of tremor, and administered cyber disease questionnaires. There was no significant difference in changes in questionnaires between the groups. The 40-59 age group showed the greatest increase in cyber disease symptoms compared to the 19-39 age group. Smoking was negatively associated with cyber illness, while a high positive and negative affect score was positively associated with cyber illness. In summary, the intensity of the tremor in VR did not affect cybernetic disease. Smoking was a protective factor, but a greater expression of affection was a risk factor for cyber disease.

And diverse research, carried out by LUU, et al (2021), explores the importance of stereopsis, the ability of the human visual system to perceive depth and three-dimensional dimension, in the virtual reality (VR) experience. Through experiments that simulated self-motion at depth with radial optical flow in participants, the study investigated the impact of global stereopsis on the perception of self-movement and spatial presence in virtual environments. Research has revealed that stereopsis is not only crucial for spatial visual perception, but also has significant implications for the VR experience. Participants with impaired stereopsis demonstrated reduced sense of self-movement, spatial presence, and severity of cybernetic illness (motion sickness-like symptoms experienced in virtual environments). Through varied test conditions, including viewing monitors with the head stationary or moving and imposing multisensory conflict conditions, the study identified that the absence of global stereopsis can attenuate cybernetic illness, but at the cost of impairing the perception of self-movement and presence in VR. This work highlights the complexity of the interaction between spatial visual perception and the VR experience, suggesting that while reducing global stereopsis

may decrease the symptoms of cybernetic illness, it may also compromise the quality of perception of movement and presence in the virtual environment.

According to UGUR and KONUKSEVEN (2022), in their study, the usability of virtual reality (VR) in motion sickness (MS) rehabilitation was investigated. Twenty normal patients and 19 patients with (MS) underwent six VR rehabilitation sessions using the game"*Roller Coaster Dreams*" in "*PlayStation VR Head Mounted Display*". The sessions took place three times a week for two weeks or twice a week for three weeks. Participants were assessed before rehabilitation, after the third and sixth sessions using the sensory organization test (TOS). The effectiveness of the rehabilitation program was analyzed by comparing the results of the TOS tests. All TOS results were compared between patients to assess the effectiveness of rehabilitation. The results showed statistically significant differences in TOS balance scores under different conditions, indicating improved stability after VR rehabilitation sessions. VR has been found to be effective and useful in the rehabilitation of motion sickness (MS) rehabilitation, making the process more fun and increasing efficiency, reducing the risk of inadaptability to exercise.

Exploring the variability in susceptibility to motion sickness, FULVIO, JI and ROKERS, (2021), propose a possible explanation based on the theory of cue conflict. According to this theory, sensory cues that lead to incompatible perceptual interpretations cause physical discomfort. Individual sensitivity to visual sensory cues, such as parallax movements, is a predictor of the severity of motion sickness symptoms. Using virtual reality, the researchers assessed the observers' sensitivity to various visual cues and induced motion sickness through stereoscopic films. Sensitivity to motion parallax cues was found to be related to the severity of motion sickness symptoms. In addition, the possible influence of sex on motion sickness was explored, but little support was found for this relationship. The results suggest that personalizing virtual reality experiences based on individual sensitivity can help mitigate the discomfort of motion sickness.

Seeking to investigate the severe symptoms of visually induced motion sickness (VIMS), according to KAUFELD, et al (2022), these symptoms may occur in optical augmented reality (AR) visualization applications. Previous studies have shown lower symptoms of VIMS with this technology, but new applications with more dynamic simulations could alter the severity of symptoms. Experiment 1 exposed participants to a static AR application, while experiment 2 involved tasks in a dynamic starfield simulation. Symptoms were assessed before and after exposure using questionnaires and a motion sickness scale. The results showed low symptoms of

VIMS in experiment 1, with predominantly oculomotor symptoms. In experiment 2, however, severe symptoms of VIMS were detected in some participants, mainly disorientation. This indicates that VIMS can be a serious concern in modern AR applications. The study also developed a new tool to measure symptoms of dizziness during exposure. The symptoms of VIMS should be considered in the design and use of future AR applications with dynamic virtual objects, such as flight training or machine maintenance work.

Another study is that of RYAN, et al (2022). which explored the effectiveness of a virtual reality learning environment (VRLE) as an educational tool in the area of obstetrics. It was conducted at a university in Ireland, involving undergraduate and postgraduate students in midwifery. The study used a qualitative and quantitative descriptive method, collecting data through a multiple-choice questionnaire and open-ended questions. The results showed no statistically significant differences in pre- and post-intervention knowledge scores. However, participants demonstrated high satisfaction and self-confidence regarding the use of VRLE as a learning modality. The most common side effects reported by participants were dizziness, disorientation, and motion sickness-like symptoms. The themes identified were related to 3D learning, visual learning, the value of educational technology, and positive learning experience.

Although VRLE does not have a significant impact on knowledge gain, its use has shown potential to improve students' learning experience, engagement, satisfaction, and self-confidence.

Virtual Reality (VR) is a growing technology, according to VICENTE, et al (2022), which uses computing to create simulated environments in various areas, such as medicine, entertainment, and gaming. However, information on the side effects of VR is limited. The research aimed to identify the most common physical side effects of therapeutic applications of VR. We consulted full articles between 2016 and 2021 that evaluated VR as a therapeutic intervention and reported side effects using the Simulator Motion Sickness Questionnaire (SSQ). We found 10 articles that met the inclusion criteria, involving 416 patients with a mean age of 24.54 years. The methodological quality of the studies was evaluated, and two articles were considered good or excellent. The most frequently reported adverse reactions were disorientation, nausea, and oculomotor disturbances, especially when monitors were worn on the head compared to tabletop systems. While VR can have positive effects as a therapeutic tool, it is important to consider the potential side events. Well-designed scientific methodologies are needed to assess effectiveness and safety before planning VR therapeutic interventions.

According to WU, et al (2020), visually induced motion sickness (VIMS) is characterized by psychophysiological discomfort and has a negative effect on executive function, which

includes the ability to inhibit inappropriate responses in changing environments. The study investigated changes in response inhibition after the occurrence of VIMS using event-related potentials (ERPs). Participants performed a two-choice task, and ERPs were recorded before (pre-test) and after a 40-minute virtual reality (VR) training session (post-test). The results showed a higher amplitude of the N2 component for deviant stimuli, a lower amplitude of the P3 component for deviant stimuli, and a delay in the latency of the P3 component after VR training. These studies suggest that VIMS is associated, in part, with response inhibition and that the N2 and P3 components related to inhibition can be used as electrophysiological indices to assess response inhibition in visually induced motion sickness (VIMS).

O "*cybersickness*", or visually induced motion sickness, as SEVINCA and ILKERB (2022) explain, is a negative effect that can affect the user experience in virtual environments (EVs) developed for virtual reality (VR).

Another research carried out was that of QIU, et al (2022), which aimed to investigate the acceptance and tolerance of a cognitive training program based on virtual reality (VR) in Chinese elderly. A program was developed that consisted of five VR cognitive training games. Fourteen seniors voluntarily participated in the VR training program from January 1 to January 22, 2022. Participants' tolerance and acceptance of VR training were assessed after the program. Of the participants, 8 (57.1%) had normal cognitive function and 6 (42.9%) had cognitive impairment. Participants tolerated the program well, with a mean total Disease Simulation Questionnaire (SSQ) score of 10.42±12.97. Regarding acceptance, 97.6% of the subjects found the VR equipment easy to use, 76.2% had a positive experience, and 57.1% found the VR devices attractive. It can be seen that VR-based cognitive training was well tolerated by Chinese elderly, without the occurrence of serious adverse events.

The studies by OH and LEE, (2021), investigated the feasibility of an immersive virtual reality (VR) game on balance and kinesis in healthy adolescents. Eleven healthy adolescents participated in the study. Three conditions were realized: baseline (measured balance without VR play), immersive VR game with fixed background, and immersive VR game with moving background. Balance and kinesia were measured, and questionnaires were used to assess kinesia. During moving bottom play, there was a significant increase in swing speed and length compared to baseline and fixed bottom play. Kinesia questionnaire scores also increased significantly during both VR games compared to baseline, being higher with the moving background.

Playing an immersive VR game with a moving background can negatively impact balance and kinesis. These results may aid in the selection of gaming content that will reduce side effects when utilizing VR devices in the future.

The use of virtual reality (VR) can cause adverse effects based on the research of PARK and LEE (2019), such as dizziness, headache, and motion sickness. It was investigated how full-immersion VR games affect static balance and adverse effects, and whether a moving or fixed game background contributes more to these problems. Static balance and adverse effects were measured in 15 healthy adults under three conditions: baseline, after a full-immersion VR game with a fixed background (15 min), and after a full-immersion VR game with a moving background (15 min). Playing a full-immersion VR game had a negative effect on static balance and caused eyestrain and dizziness. The speed and length of the oscillation increased significantly in the game with a moving background compared to the baseline and the game with a fixed bottom ($p < 0.05$). VR symptom questionnaires were also significantly higher in this case. Therefore, it is preferable to use only full-immersion VR games with fixed backgrounds in rehabilitation interventions in order to reduce adverse effects.

Another way to reduce discomfort caused by motion sickness was presented in the research by NG, CHAN and LAU (2019), which investigated whether coupling physical movements to visual stimuli in virtual reality (VR) could reduce the discomfort caused by motion sickness. A VR system coupled with a physical movement, developed on a motion platform, was used, which provided vestibular cues to complement the visual movement of a head visualization device (HMD). Three conditions were tested: visual rotation only (stationary), synchronized physical-visual movement (synchronous) and vestibular movement with a self-reported visual environment. The results showed that when users experienced the synchronized visuo-vestibular condition, they reported lower subjective motion sickness score and greater overall comfort in the experience. This indicates that a motion-coupled system, seamlessly integrated into VR, can mitigate the symptoms of motion sickness.

Another investigation, carried out by KESHAVARZ, et al (2021), was the investigation of Machine Learning techniques "*Machine Learning*ML in conjunction with physiological measures could be used to detect and predict in real time the severity of visually induced motion sickness (VIMS), such as that experienced when using smartphones or Virtual Reality. A group of 43 healthy young adults was exposed to a VIMS-inducing video for 15 minutes, and VIMS severity was subjectively measured during the video using the Fast Motion Sickness (FMS) scale, as well as before and after the video using the Simulator Disease Questionnaire (SSQ).

About 72% of participants experienced VIMS in this study. The results showed that changes in facial skin temperature and body movements had the strongest relationship with VIMS. ML models revealed a mean correlation between physiological measures and minute-by-minute FMS scores. An acceptable rating score was found to distinguish between sick and non-sick participants. These findings suggest that physiological measures may be useful for measuring VIMS, but are not a reliable stand-alone method for detecting or predicting VIMS severity in real time.

In the research by WOO, et al (2022), the recovery time from virtual reality (VR) disease in participants after watching a VR video, using electroencephalography (EEG), was investigated. Forty participants were previously tested using a motion sickness susceptibility questionnaire (MSSQ) and classified into two groups: sensitive and non-sensitive to RV disease. The simulator disease questionnaire (SSQ) and EEG were used to assess RV disease. The SSQ score increased significantly in both groups after watching the VR video. The recovery time based on the SSQ was 11.3 ± 6.6 minutes for the sensitive group and 9.1 ± 5.2 minutes for the non-sensitive group, with no significant difference between the groups. The median recovery time based on EEG data was 11.5 ± 7.1 minutes in both groups. EEG data showed a significant increase in delta wave activity in all brain areas. There was no statistical difference between the groups in the time to recovery from RV disease based on individual characteristics. However, it was confirmed that subjective and objective recovery from RV sickness required at least 11.5 minutes. These results may provide insight into recovery times from RV disease.

LIM, et al, (2020), in a diverse research, investigated whether the use of electroencephalogram (EEG) as an objective method to assess virtual reality (VR) disease. A total of 21 participants who were sensitive to VR disease were recruited, selected based on Motion Sickness Susceptibility Questionnaire (MSSQ) scores. RV disease was assessed twice, one week apart, using EEG and a Sham Disease Questionnaire (SSQ). The reliability of the EEG was evaluated by means of internal consistency and interclass reliability (ICC) analyses, revealing that the delta and alpha waves in two areas (frontal and central) showed consistency. A significant difference was observed in delta and alpha waves between baseline and RV conditions in both areas. These results indicate that EEG may be a reliable method for assessing RV disease, providing information about specific waves and areas associated with the disease. These findings may contribute to future research in the evaluation of RV disease.

In research conducted by SMYTH, et al (2020), a new visuospatial training tool was developed to reduce susceptibility to motion sickness. A total of 42 participants were recruited

who underwent driving simulator tests and road tests. Initial measurements of visuospatial abilities and motion sickness were performed. After a 14-day training period, participants showed 40% improvement in visuospatial skills. This improvement resulted in a 51% reduction in motion sickness in the simulator (with 60% fewer participants dropping out) and a 58% reduction in road testing. The study demonstrated an effective method to reduce susceptibility to motion sickness through visuospatial training. These results have important implications for motion sickness research, especially in the context of autonomous vehicles.

According to BREDIKHIN, et al (2022), in their research, which addresses motion sickness, a disorder that affects 5 to 15% of adults and can have a negative impact on daily and professional activities, especially for maritime specialists. The goal is to develop training techniques and reduce the symptoms of motion sickness using virtual reality (VR) technologies. VR allows you to simulate varied visual environments and dynamically alter viewing angles to investigate its direct effect on motion sickness symptoms. The research involved 50 participants and used a research methodology to identify symptoms and conduct training. The results were evaluated to verify the effectiveness of the approach.

It is important to investigate, as LAESSOE, et al (2022) point out, whether individual characteristics of balance and tendency to motion sickness are related to vulnerability to cybernetic disease, a side effect caused by the use of virtual reality with head-mounted displays. Healthy young people were exposed to a VR application for four minutes, and their symptoms of cyber illness were recorded by a questionnaire. Participants were negatively affected by VR exposure, with increased discomfort and symptoms of nausea and disorientation. Surprisingly, participants have already reported discomfort after the initial balance assessment. Those prone to motion sickness were most affected by this challenge to sensory integration. Although postural instability was observed during exposure to VR, no individual balance characteristics associated with vulnerability to cyber disease were identified. In addition, the adverse effect of the sensory orientation test affected subgroup differences in vulnerability to cybersickness.

Another investigation by PETTIJOHN, et al (2022), compared simulator disease symptoms in participants using virtual reality (VR) or augmented reality (AR) headsets. It also investigated the effect of physical movement on symptoms. During a simulation, participants wore VR and AR headsets on a motion platform while firing at enemy ships under three motion conditions: no physical motion, synchronous motion (physical and displayed motion attached), and asynchronous motion (physical motion not corresponding to the display). Symptoms increased over time, but there were no significant differences regarding headset type or

movement. The RV condition showed higher accuracy and faster response time to start the fire. More research is needed to investigate whether these results hold up in more extreme movements. The use of VR or AR headsets for training in smooth motion conditions is feasible and may be allowed during deployment under normal conditions.

Other studies, such as the one carried out by JANG, et al (2022), aim to investigate the "*cybersickness*" in people with sensitivity to motion sickness during the virtual reality (VR) experience. A total of 40 men in their twenties were selected, divided into a sensitive group and a non-sensitive group. Participants were exposed to VR content and their symptoms were assessed using electroencephalography (EEG) and the "*Simulator Sickness Questionnaire*" (SSQ). The results showed a significant increase in SSQ scores after exposure to VR content in both groups. The sensitive group had lower brain power in the beta and gamma bands compared to the non-sensitive group. In addition, changes in neural oscillations were observed, with an increase in delta and a decrease in alpha in the condition of "*cybersickness*". These findings suggest that the "*cybersickness*" is related to individual differences in sensitivity to motion sickness and may be reflected in changes in brain activity measured by EEG. However, more research is needed to better understand the underlying mechanisms and develop strategies to reduce "cybersickness" during the VR experience.

According to WIENRICH, OBREMSKI and ISRAEL (2022), in their research two experiments were presented that evaluate the effect of a virtual nose on simulator disease and on the gaming experience in two virtual reality games. The pilot study compared the implementation of the sensory conflict theory (habituation) with the suggestion of the resting frame hypothesis (virtual nose). Habituality contributed significantly to the reduction of simulator disease, while the low-fidelity prototype of the virtual nose had no impact. The main study utilized an improved virtual nose model and investigated the impact of consciousness in relation to the virtual nose. The improved nose has demonstrated that the use of a virtual nose reduces simulator sickness, without affecting the gaming experience. Additional results showed no significant impact of resting frame awareness, either on simulator disease or on the gaming experience. The results of the study support the idea that a stable virtual nose can be used in demanding virtual reality applications to reduce simulator sickness, without affecting the gaming experience.

TSENG and GIAU (2021), conducted a research that investigated the potential adoption of virtual reality (VR) as a pre-occupancy assessment tool (Pre-OE) in older people, focusing on technology adoption and spatial cognition. An experimental study was conducted with the

participation of 32 healthy older adults aged 60 years or older, divided equally into two groups: immersive VR and non-immersive VR. The results indicated that immersive VR is promising and safe for application in the elderly, with no significant records of symptoms of sham disease. The use of immersive VR also provided a greater sense of presence and more accurate spatial cognition. The qualitative data showed positive aspects from the perspective of the participants. Immersive virtual reality (VR) is feasible and effective as a complement to conventional methods for the assessment of preoccupancy in older people. The research highlights the importance of understanding the needs and satisfaction of older adults in the interior design process, and VR can play a significant role in this context.

Other research addresses cyber illness by KOURTESIS, et al (2022), which is a drawback of virtual reality (VR) that affects users' cognitive and motor skills. The study developed two versions of the VR Cyber Illness Questionnaire (CSQ-VR): a paper-and-pencil version and a 3D-VR version. The validity and comparison of the CSQ-VR with the Simulator Sickness Questionnaire (SSQ) and the Virtual Reality Sickness Questionnaire (VRSQ) were performed. Thirty-nine participants were exposed to three VR rides with linear and angular accelerations, while assessments of cognitive and psychomotor skills were conducted. Both versions of the CSQ-VR showed superior validity and internal consistency compared to the SSQ and VRSQ. In addition, CSQ-VR scores were more efficient in detecting a temporary decline in performance due to cyber illness. Pupil size has been identified as a significant predictor of cybernetic disease intensity. The CSQ-VR is a valid tool for assessing cybernetic illness in VR exposure, with psychometric properties superior to SSQ and VRSQ. CSQ-VR also benefits from pupil size examination as a biomarker of cybernetic disease.

METHODOLOGY

The research methodology contemplated in this article is the systematic literature review (RSL) and bibliometric analysis, which aims to elucidate the research theme, that is, the use of m Study on the discomfort of virtual reality goggles of augmented reality in medicine from a systematic approach, as well as the key questions elaborated. The systematic review of the literature aims to organize and determine the best literature to be used, as well as the adoption of bibliometric analysis, which would be a quantitative analysis of data and information.

> The purpose of the RSL is to search the literature on a specific topic, providing a summary of the evidence found in relation to a specific subject, organizing and explaining in a systematic way the way in which the searches, analysis and synthesis of the retrieved publications were carried out (SAMPAIO; MANCINI, 2007 apud DELGADO LOPES, et al, 2019).

The method used in this article, started on June 01, 2022, is based on the method addressed by FERENHOF; FERNANDES cited in the work and used in the research by DELGADO LOPES, et al, 2019.

> The SSF is a non-random or exploratory method, as it follows a rigorous methodological procedure that ensures repeatability of the research, minimizing researchers' tendencies that may occur derived from the choice of random documents (FERENHOF; FERNANDES, 2016 apud DELGADO LOPES, et al, 2019).

ANALYSIS AND DISCUSSION OF RESULTS

The SSF method of analysis contains a table with the activities that comprise the research protocol as follows.

Table 1: Definition of the Research Protocol

Activity 1. Search strategy	The search method used the English terms "Augmented Reality", "Virtual Reality"; "Cybersickness"; "Motion Sickness". The objective of the search was to find results related to the research proposal, such as the use of virtual reality glasses and some consequences or disturbances, such as "cybersickness" and "motion sickness", caused by the use of virtual reality. The inclusion and exclusion criterion was to contain the keywords searched in "*IEEE Xplore*", "*Science Direct*", "*Articles Nature*" and "*PubMed*", selecting articles that contained in the title and text the keywords adopted in this search. The articles made available through a username and password registered at UNESC – University of the Extreme South of Santa Catarina, as well as the proper authorization to download the files. Language: English and Portuguese.
Activity 2. Database query	The database chosen was "*IEEE Xplore*", "*Science Direct*", "*Articles Nature*" and "*PubMed*". The research searches were carried out as follows, in order to assist the research, using citations, books, newspapers, magazines, conferences, with the help of keywords: "Augmented Reality", "Virtual Reality"; "Cybersickness"; "Motion Sickness". A total of 187 titles were found, without informing the year of publication or other information in order to obtain the greatest amount of information for the implementation of the proposed research.
Activity 3. Organization of bibliographies	To manage the bibliographies, Word was used to search for applications, and references were inserted.
Activity 4. Standardised selection of articles	The standardized selection phase of the articles involved the reading of the titles and their referred articles, and they were selected because they encompassed the questions proposed in the research. When choosing the articles, 185 articles were included and after a careful reading of each article, the total of 66 titles was maintained.
Activity 5. Portfolio composition	In the phase of composition of the portfolio and after reading the archives chosen to compose the present research work, a total of 66 articles remained, 2 articles being eliminated, reaching in the end 64 articles in the finished portfolio.

Table 2: Activities and number of documents retrieved

Activity	Number of documents
Search the bases	185 results in total
Deleting Duplicate Documents	108
First filter (Reading titles, abstracts and keywords)	66
Full text according to inclusion and exclusion criteria	66
Total number of documents available, read in full	77
Final Portfolio	64

Table 3: Final portfolio

	Authors	Year	Title	Thematic
01	AL-ASHWAL, Wadhah, et al.	2021	**Cybersickness Measurement and Evaluation During Flying a Helicopter in Different Weather Conditions in Virtual Reality**.	Measurement and Evaluation of Motion Sickness During the Flight Simulation of a Helicopter in Different Weather Conditions in Virtual Reality.
02	ALIREZA, Mazloumi Gavgani, et al.	2018	**A comparative study of cybersickness during exposure to virtual reality and "classic" motion sickness: are they different?**	Comparative study of cybersicness and motion sicness.
03	ANG. Samuel, QUARLES. Antonio John..	2022	**You're in for a Bumpy Ride! Uneven Terrain Increases Cybersickness While Navigating with Head Mounted Displays.**	Uneven Terrain Increases Motion Sickness When Navigating with Head-Mounted Displays.
04	BREDIKHIN, Artem, et al.	2022	**Diagnostics of motion sickness (kinetosis) and training of resistance to it in VR simulators.**	Diagnosis of motion sickness and resistance training in virtual reality.
05	CHATTHA. Umer Asghar, et al.	2020	**Motion Sickness in Virtual Reality:An Empirical Evaluation.**	Motion sickness and virtual reality and their theoretical evolution.
06	CHUL CHUN, Gabriel Yong, et al.	2022	Evaluation of sensory discomfort caused by virtual reality stimulation in volunteers with and without motion sickness.	Evaluation of discomfort in the use of virtual reality.
07	Chusethagarn, Davit, Visuttivisheth, Vasaka i Haga, Jason.	2018	**A Prototype of Collaborative Augement Reality Environment for Hololens**.	Prototype of Augmented Reality Collaborative Environment for Hololens.
08	FERENHOF, Hélio Aisenberg; FERNANDES, Roberto Fabiano.	2019	**Demystifying the literature review as a basis for scientific writing: SSF method**.	Literature review.
09	FULVIO, Jacqueline M., JI, Mohan e ROKERS, Bas.	2021	**Variations in visual sensitivity predict motion sickness in virtual reality**.	Variations in visual sensitivity predict motion sickness in virtual reality.
10	GEMERT, Thomas Van; BERSTROM, Joanna.	2021	**Evaluating VR Sickness in VR Locomotion Techniques.**	Assessing VR motion sickness in virtual reality locomotion techniques.
11	JANG, Kyoung-Mi, et al.	2022	**Estimating objective (EEG) and subjective (SSQ) cybersickness in people with susceptibility to motion sickness.**	Estimating objective (EEG) and subjective (SSQ) cyber motion sickness in people with susceptibility to motion sickness.
12	KAUFELD, Mara, et al**.**	2022	**Optical see-through augmented reality can induce severe motion sickness**.	Optical augmented reality can induce severe motion sickness.

13	KIM, Hyewon, et al.	2021	**Clinical predictors of cybersickness in virtual reality (VR) among highly stressed people**.	Clinical predictors of motion sickness in virtual reality (VR) among highly stressed people.
14	KIM, Hyun, et al.	2018	**Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment. Applied Ergonomics.**	Virtual Reality Motion Sickness Questionnaire (VRSQ): Motion Sickness Measurement Index in a Virtual Reality Environment. Applied Ergonomics.
15	KIM. Jinwoo, et al.	2022	**A Deep Motion Sickness Predictor Induced by Visual Stimuli in Virtual Reality.**	A profound predictor of motion sickness induced by visual stimuli in Virtual Reality.
16	KIM. Woojae, et al.	2021	**VR Sickness Versus VR Presence: A Statistical Prediction Model**.	Virtual Reality Motion Sickness vs. Virtual Reality Presence: A Statistical Prediction Model.
17	KESHAVARZ, Behrang, et al.	2022	**Detecting and predicting visually induced motion sickness with physiological measures in combination with machine learning techniques**.	Detecting and predicting visually induced motion sickness with physiological measures in combination with machine learning techniques.
18	KOACH, Andreas, et al.	2018	**The Neurophysiology and Treatment of Motion Sickness.**	The Neurophysiology and Treatment of Motion Sickness.
19	KOURTESIS, Panagiotis, et al.	2022	**Cybersickness in Virtual Reality Questionnaire (CSQ-VR): A Validation and Comparison against SSQ and VRSQ**.	Virtual Reality Motion Sickness Questionnaire (CSQ-VR): A Validation and Comparison with SSQ and VRSQ.
20	KUO, Po-Chen, et al.	2021	**VR Sickness Assessment with Perception Priorand Hybrid Temporal Features**.	Assessment of Virtual Reality Motion Sickness with Perception Priority and Hybrid Temporal Resources.
21	KYOUNG-MI, Jang, et al.	2022	**Estimating objective (EEG) and subjective (SSQ) cybersickness in people with susceptibility to motion sickness.**	Estimating objective (EEG) and subjective (SSQ) Virtual Reality Motion Sickness in people with susceptibility to motion sickness.
22	LAESSOE U, Abrahamsen S, et al.	2022	**Motion sickness and cybersickness - Sensory mismatch**.	Motion sickness and virtual reality motion sickness - Sensory maladjustment.

23	LIÃO, CHUNG-YEN; et al.	2020	**Using EEG and Deep Learning to Predict MotionSickness Under Wearing a Virtual Reality Device**.	Using EEG and Deep Learning to Predict Motion Sickness When Using a Virtual Reality Device.
24	LIM, Hyun Kyoon, et al.	2020	**Test-retest reliability of the virtual reality sickness evaluation using electroencephalography (EEG).**	Test-retest reliability of motion sickness assessment in virtual reality using electroencephalography (EEG).
25	LOHMAN. Jesse e TURCHET. Luca.	2022	**Evaluating Cybersickness of Walking on anOmnidirectional Treadmill in Virtual Reality.**	Evolution of Cybersicness and Virtual Reality.
26	LUU, Wilson, et al.	2021	**Effects of stereopsis on vection, presence and cybersickness in headmounted display (HMD) virtual reality.**	Effects of stereopsis on vection, presence, and motion sickness in virtual reality with the use of Head Mounted Display (HMD).
27	MAHMOOD, Faraz, et al.	2018	**Augmented Reality and Ultrasound Education: Initial Experience.**	Augmented Reality in education.
28	NG, Drian K.T., CHAN, Leith K.Y. e LAU, Henry Y.K.	2019	**A study of cybersickness and sensory conflict theory using a motion-coupled virtual reality system**.	A study on motion sickness and sensory conflict theory using a virtual reality system with motion attached.
29	NOH, Seron, PARK, Seunghoon; KIM, Gerard J.	2022	**OnShipVR: Reducing Sea-sickness through Virtual Contents with Synchronized and Amplified Actual Ship Rotation.**	OnShipVR: Reducing seasickness through virtual content with amplified rotation synchronized with the actual movement of the ship.
30	Oh, Haijin A. Lee, Guichang.	2021	**Feasibility of full immersive virtual reality video game on balance and cybersickness of healthy adolescentes**.	Feasibility of a fully immersive virtual reality video game in the balance and motion sickness aspects of virtual reality in healthy adolescents.
31	OKUNO. Satoshi, SHIMIZU. Sota	2022	**Study on Displaying Images to Prevent VR Sicknessas Maintaining Rich-Presence.**	Study on displaying images to prevent virtual reality motion sickness while maintaining rich presence.
32	Park. Umm-Hyun, Yun. Cowan, Cam.	2023	**Reducing VR Sickness by Directing User Gaze to Motion Singularity Point/Region as Effective Rest Frame.**	Reducing virtual reality motion sickness by directing the user's gaze to the point/region of singularity of movement as an

				effective resting frame.
33	PARK, SoHu by LEE, GyuChang.	2020	**Full-immersion virtual reality: Adverse effects related to static balance**.	Full Immersion Virtual Reality: Adverse Effects Related to Static Balance.
34	PETTIJOHN, Kyle A., et al.		**Virtual and augmented reality in a simulated naval engagement: Preliminary comparisons of simulator sickness and human performance**.	Virtual and Augmented Reality in a Simulated Naval Engagement: Preliminary Comparisons of Simulator Motion Sickness and Human Performance.
35	PÕHLMANN, Katharina Margareta Theresa, O'HARE, Louise, FÕCKER, Julia.	2021	**Is Virtual Reality Sickness Elicited by Illusory Motion Affected by Genderand Prior Video Gaming Experience?**	Virtual reality motion sickness triggered by illusory motion is affected by genre and previous video game experience.
36	QIU, Ruxia, et al.	2022	**Virtual reality-based targeted cognitive training program for Chinese older adults: A feasibility study**.	Virtual Reality-Based Targeted Cognitive Training Program for Chinese Older Adults: A Feasibility Study.
37	Rahmi, Kasra, Banigan, Colin E. Ragan, Eric D.	2020	**Scene Transitions and Teleportation in Virtual Reality and the Implications for Spatial Awareness and Sickness**.	Scene transitions and teleportation in virtual reality and the implications for spatial awareness and motion sickness.
38	RYAN, Grace, et al.	2022	**Virtual reality in midwifery education: A mixed methods study to assess learning and understanding**.	Virtual Reality in Midwifery Education: A Mixed-Methods Study to Assess Learning and Comprehension.
39	SALIMI Zohreh, FERGUSON-PELL, Martin Willian.	2021	**Motion Sickness and Sense of Presence in a Virtual Reality Environment Developed for ManualWheelchair Users, with Three Different Approaches**.	Motion sickness and a sense of presence in a virtual reality environment designed for manual wheelchair users, with three different approaches.
40	Sampaio, R.; Mancini, Mom.	2019	**Systematic review studies**: a guide to a careful synthesis of scientific evidence.	Systematic Review.
50	SEVINCA, Volkan e ILKERB, Berkman Mehmet.	2019	**Psychometric evaluation of Simulator Sickness Questionnaire and its variants as a measure of cybersickness in consumer virtual environments**.	Psychometric evaluation of the Simulator Motion Sickness Questionnaire and its variants as a measure of virtual reality motion sickness in virtual consumption environments.

51	SMYTH, Joseph, et al..	2020	**A novel method for reducing motion sickness susceptibility through training visuospatial ability – A two-part study**.	An Innovative Method to Reduce Susceptibility to Motion Sickness Through Visuospatial Skill Training – A Two-Part Study.
52	SZPAK. Ancrêt, et al.	2022	**Getting the Most out of Virtual Reality: Evaluating Short Breaks to Reduce Cybersickness and Cognitive Aftereffects**.	Making the Most of Virtual Reality: Evaluating Short Breaks to Reduce Motion Sickness and Subsequent Cognitive Effects.
53	TAI, Yixin; YANG, Yu; MONEY, Xiaotian.	2022	**Development of VR Motion Sickness Test Platform Based on UE.**	Development of a motion sickness test platform in Virtual Reality based on Unreal Engine (UE).
54	TSENG, Kevin C. E RICH, Do Thi Ngoc.	2021	**A feasibility study of using virtual reality as a pre-occupancy evaluation tool for the elderly.**	A feasibility study on the use of Virtual Reality as a pre-occupancy assessment tool for the elderly.
55	UGUR, Emel e KONUKSEVEN, Bahriye Özlem.	2022	**The potential use of virtual reality in vestibular rehabilitation of motion sickness.**	The potential use of Virtual Reality in vestibular rehabilitation of motion sickness.
56	WANG. Jialin, et al.	2022	**Real-time Prediction of Simulator Sickness in VirtualReality Games.**	Real-time prediction of motion sickness in Virtual Reality games.
57	WIENRICH, Carolin, OBREMSKI, David e ISRAEL, Johann Habakuk.	2022	**Repeated experience or a virtual nose to reduce simulator sickness? – Investigating prediction of the sensorial conflict theory and the rest-frame hypothesis in two virtual games.**	Repeat experience or a virtual nose to reduce motion sickness? - Investigating the prediction of sensory conflict theory and frame of reference hypothesis in two virtual games.
58	WOJCIECHOWSKI. Przemyslaw, WÓJTOWICZ.	2022	**Konrad. Simulator sickness and cybersickness as significant indicators in a primary selection of candidates forFPV drone piloting**.	Simulator motion sickness and virtual reality motion sickness as significant indicators in the initial selection of candidates for FPV drone piloting.
59	WOO, Ye Shin, et al.	2022	**Recovery time from VR sickness due to susceptibility: Objectiveand quantitative evaluation using electroencephalography**.	Recovery time from virtual reality motion sickness due to susceptibility: objective and quantitative assessment using electroencephalography.

60	WU, Jintao, et al.	2020	**Inhibition-related N2 and P3: Indicators of visually induced motionsickness (VIMS).**	N2 and P3 related to inhibition: indicators of visually induced motion sickness (IMV).
61	YEO, Sang Seok, KWON, Jung Won e PARK, Seo Yoon.	2022	**EEGbased analysis of various sensory stimulation effects to reduce visually induced motionsickness in virtual reality.**	EEG-based analysis of the effects of various forms of sensory stimulation to reduce visually induced motion sickness in virtual reality.
62	VENKATAKRISHNAN, Roshan, et al.	2020	**Comparative Evaluation of the Effects of Motion Control on Cybersickness in Immersive Virtual Environments.**	Comparative evaluation of the effects of motion control on motion sickness in immersive virtual environments.
63	VENKATAKRISHNAN, Roshan, et al.	2020	**Comparative Evaluation of the Effects of Motion Control on Cybersickness in Immersive Virtual Environments.**	Comparative evaluation of the effects of motion control on motion sickness in immersive virtual environments.
64	ZHANG, Chen.	2020	**Investigation on Motion Sickness in Virtual RealityEnvironment from the Perspective of UserExperience.**	Research on motion sickness in virtual reality environments from the perspective of user experience.

Table 4: Key findings on the research questions

Issues	Discoveries
1 – What is the objective of the research?	To evaluate the users of virtual reality glasses with the application of a VRSQ – "Virtual Reality Sickness Questionnaire", in order to measure the symptoms during the use of the glasses.
2 – What is the focus of the bibliographic research?	Conduct a literature search focusing on discomfort in users of virtual reality glasses, these side effects are known as "cybersickness" or "simulator sickness" and are similar to the symptoms of motion sickness that some people experience when traveling by car, plane, or boat;
3 – What are the challenges for the implementation of the research?	Carry out the application of a questionnaire to a certain number of people in order to verify the possible occurrence of symptoms during use, which may compromise the use of virtual reality glasses.
4 – How will the results of the field research be worked on?	The information will be analysed and the results will be displayed in tables or graphs;

CONTRIBUTIONS OF THE SYSTEMATIC REVIEW

The present systematic review addresses the persistent challenge of cybersickness associated with the use of virtual reality (VR) glasses, a topic of increasing importance given the advancement and expansion of VR in various fields. Through the analysis of data and information collected from relevant studies, this work contributes significantly to the

understanding of the underlying mechanisms and strategies for mitigating discomfort in virtual environments.

Comparatively, previous studies, such as those conducted by Kourtesis et al. (2022), focused on the validation of *cybersickness* assessment tools, such as the CSQ-VR, providing a basis for assessing the severity of symptoms in different VR contexts. The present review expands this understanding, not only by consolidating these measurement tools as fundamental in the assessment of discomfort, but also by exploring practical strategies for symptom mitigation, such as adapting the design of VR content and the importance of strategic pauses during exposure.

One of the most valuable aspects of this study is its contribution to the identification of gaps in the existing literature, particularly in the need for future research that explores the impact of individual variables, such as predisposition to motion sickness and familiarity with virtual environments, on susceptibility to *cybersickness*". In addition, there is a need for studies that evaluate the effectiveness of different mitigation techniques in specific populations, such as the elderly and individuals with pre-existing health conditions.

The review also illuminates the importance of considering user experience in the design of virtual environments, suggesting that a user-centered approach, which takes into account both the benefits and potential discomforts of VR, is crucial for the advancement of the technology and its large-scale adoption. The discussion of the balance between immersion and comfort offers valuable insights for developers and researchers in the field.

In summary, this work not only consolidates existing knowledge about cybersickness in virtual reality, but also points out avenues for future research, highlighting the complexity of the phenomenon and the need for multidisciplinary approaches to understand and mitigate it effectively. Thus, it contributes significantly to the field of virtual reality by emphasizing the importance of inclusive and accessible designs that promote positive experiences for all users.

FINAL THOUGHTS

The present systematic review of the literature and bibliometric analysis began with a search in a database of "*IEEE X*plore", "*Science Direct*", "*Articles Nature*" and "*PubMed*", initially contemplating 185 articles, which after the detailed analysis 121 articles were excluded, totaling 64 articles in the final portfolio. The research initially addressed the theme "A study on the discomfort of virtual reality glasses as: a systematic review".

The present research is based on the growing use of virtual reality in various areas, such as games, training and therapies, and on the importance of ensuring the user experience in terms of comfort and safety. Therefore, the research aims to verify the possibility of discomfort in VR glasses, by applying a questionnaire to a certain number of people to better evaluate the results in order to improve the user experience and increase the adoption of the technology in different areas. This is important because VR has great potential to transform the way people interact with the digital world and can bring significant benefits to areas such as healthcare, education, and entertainment.

In the second guiding question of the research, presented in chart 4 above, we emphasize that the basis of the research is the discomfort of the user of virtual reality glasses, these side effects are known as "*cybersickness*" or "*simulator sickness*" and are similar to the motion sickness symptoms that some people experience when traveling by car, plane, or boat.

In item 3 of chart 4, we present the challenges for the implementation of the research, which is to apply a questionnaire to a certain number of people in order to verify the possible occurrence of symptoms during use, which may compromise the use of virtual reality glasses.

We conclude that both Virtual Reality (VR) and Augmented Reality (AR) have the potential to offer immersive and interactive experiences to users. However, the discomfort and dizziness associated with prolonged use of VR goggles may limit the adoption of these technologies. It is essential to understand side effects, such as cybersickness or simulator *sickness*, and develop strategies to minimize them. In addition, collaboration and information sharing are challenges faced by VR and AR technologies. Collaborative environments that use AR, such as HoloLens glasses, have been proposed as innovative solutions to allow multiple users to interact and view data in the same space, facilitating the exchange of information and more focused discussions.

To drive the adoption of these technologies, it is necessary to overcome the challenges related to discomfort and dizziness while improving the user experience. This will allow you to explore the full potential of VR and AR in different fields such as gaming, entertainment, education, and training. Understanding side effects and developing strategies to minimize them not only improves the user experience but also opens up new possibilities for interaction and immersion. By overcoming these challenges, we can make the most of the potential of VR and AR, driving innovation and transforming the way people interact with the digital world in a variety of areas.

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