Designing VR Experiences For Movies and Sports That Mitigate Cybersickness

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MSHF 618 Human Factors in Virtual and Simulated Environments

Abstract

Virtual reality has revolutionized entertainment, offering immersive and interactive experiences across gaming, movies, sports, and live events. Despite its potential, VR adoption faces significant barriers due to cybersickness, a condition characterized by symptoms of nausea, dizziness, headaches, and eye strain resulting from sensory conflicts in VR environments. The causes, effects, and mitigation strategies for cybersickness are examined, focusing on its implications for producing VR content in movies and live sports. Key factors that contribute to cybersickness are identified, including visual-vestibular conflicts, technical issues such as low frame rates and latency, and user-specific variables like susceptibility to motion sickness. Continuous locomotion techniques, abrupt camera movements, and dynamic scenes common in sports and films are highlighted as contributors to cybersickness, complicating efforts to create immersive yet comfortable VR experiences. Mitigation strategies such as field-of-view adjustments, depth-of-field blurring, stabilization techniques, and high-quality VR headsets are essential for reducing symptoms. Overcoming the challenges of cybersickness is crucial for VR to achieve its potential as a mainstream medium for entertainment. Continued advancements in VR technology and design practices will be essential to overcoming this barrier, and enabling broader audience adoption.

Virtual reality in entertainment spans a range of applications, including gaming, movies, live events, theme parks, and educational content. VR is changing how users consume content, creating immersive environments where users can interact with 3D objects, while providing the user a lifelike experience. VR has the ability to create a plethora of experiences that may not exist in real life, or situations that could be dangerous for the user, while providing the user exposure to those situations in a safe, controlled space. VR also has the potential to build social spaces, where users can meet and interact with people from different parts of the world. In that sense, VR can offer the psychological advantages of both escapism and social interaction (Hamad & Jia, 2022).

The application of VR is most notable in the entertainment industry. Initially marketed towards gaming, VR is now offering media experiences in movies and sports, allowing users greater control of their attention and focus when watching videos (Hamad & Jia, 2022). VR has transformed the movie industry by offering immersive and interactive experiences that go beyond traditional storytelling, with animated stories achieving the most success. 360-degree films allow users to explore scenes from all angles, becoming active participants of the story rather than passive observers. Similar to a choose your own adventure story, VR movies with interactive storytelling allow the user to influence the narrative or explore different perspectives within the virtual environment. VR has also revolutionized live sports by enhancing how fans experience games and events. Fans can watch games as if they were in a stadium, with 360-degree views from various vantage points, providing the experience of being courtside or goal-side. VR in live sports allows worldwide fans to virtually attend games without traveling to the arena, while allowing users to choose camera angles and viewpoints to create a tailored viewing experience.

Users can engage with VR using traditional devices such as laptops, computers, or smartphones. However, a fully immersive virtual reality experience is not yet possible without a VR headset. VR headsets are specialized devices designed to visually and audibly transport users to a simulated 3D environment, while sensors in the headset track their movements, and update the view in real-time. The tracking sensors include gyroscopes that track orientation, accelerometers that track movement, and cameras that track the user's hand movements. The headset must align the user's physical movements with the virtual elements to create a seamless experience. VR experiences may also integrate gloves or controllers, while specialized headsets support voice commands and eye tracking. Audio is an important aspect of immersion, with headsets including spatial audio to simulate sounds heard from various distances and directions.

Despite the advantages of VR, current VR technology must address its limitations before it can reach wider audience adoption. A critical issue with VR usage is cybersickness, also known as virtual simulator sickness, a condition that describes the negative effects users experience during or after immersion into virtual reality. Symptoms of cybersickness are similar to motion sickness, including eye strain, dizziness, nausea, and headaches. Cybersickness usually appears approximately 10–15 minutes after immersion into a VR environment, and symptoms usually disappear around 15 minutes after leaving the VR environment, while some people experience aftereffects that can persist for hours (Page et al., 2023). Although the causes of cybersickness are not completely understood, the most widely cited theory is the sensory conflict hypothesis. This theory proposes that conflicts arise between the different senses when the visual system perceives motion, while the vestibular system and the proprioceptive system do not sense any movement, creating a mismatch between the senses that can lead to feelings of disorientation and nausea (Norouzi et al., 2018).

Some researchers believe that individual susceptibility to cybersickness is related to individual factors, including a person's ability to quickly adapt to conflicting sensory cues (Davis et al., 2014). In addition, incidents of cybersickness are related to poor control over VR, predisposition to motion sickness, degree of immersion, and VR tasks that increase in rotation speed (Kim et al., 2021). Health factors related to fatigue, illness, and medication use can also influence a person's susceptibility to cybersickness, all situations that can affect the body's sensory processing and regulatory systems (Norouzi et al., 2018). Prolonged exposure to a VR environment can increase the probability of cybersickness, generally leading to more severe symptoms. However, individuals with previous exposure to VR may develop a tolerance to cybersickness, consistent with the observation that repeated exposure to motion sickness inducing stimuli can lead to habituation (Stanney et al., 2003).

Technical factors that can lead to cybersickness include lag, low frame rates, and inaccurate motion tracking. These issues can create sensory conflicts and disrupt the user's sense of immersion, making it more difficult for the brain to process the virtual experience. Flickering caused by low framerates can lead to eye fatigue and headaches, while lags caused by long latencies can increase sensory conflicts, culminating to stronger symptoms of cybersickness (Garrido et al., 2022). Continuous locomotion, where the user moves continuously through the VR environment using a controller, tends to cause more cybersickness, specifically continuous locomotion techniques with mismatched stimuli such as joystick-based movements (Caserman et al., 2021). Discrete locomotion techniques that enable natural walking are associated with less cybersickness, such as teleportation or room-scale setups. VR headsets with a wide field of view FOV may increase immersion but can also increase cybersickness, while a narrow FOV can also distort the perception of motion and contribute to cybersickness (Garrido et al., 2022).

Producing movies and sports in VR can be notably complex when seeking to maintain entertainment value while mitigating cybersickness. Filmmakers and broadcasters must balance immersion with smooth, natural motion to avoid overwhelming viewers. Rapid camera pans, sudden transitions, or unexpected changes in perspective can trigger cybersickness, especially in sports where action is dynamic (Biswas et al., 2024). Furthermore, placing cameras in positions that create a stable and natural viewing experience is critical. Movies should create scenes that don't overly stimulate with erratic movement, while sideline or fixed-position views in sports work better than overly dynamic camera placements (Gruber et al., 2023). A distinct attribute of VR is the ability for viewers to look in any direction. However, this can lead to cybersickness when abrupt camera shifts attempt to guide viewer attention. Furthermore, dynamic elements in VR can cause a sensory mismatch, such as following fast-moving objects like a soccer ball in sports or a car chase in movies, especially when the virtual camera simulates movement but the viewer remains stationary.

Although a single solution to completely eliminate cybersickness has not been found, and balancing immersion with comfort has significant challenges, mitigation strategies do exist to reduce the symptoms. VR designers can employ strategies such as FOV adjustments, depth of field (DOF) blurring, rest frames, and optical flow manipulation (Biswas et al., 2024). Restricting the FOV, a technique known as "vignetting" or "tunneling," minimizes peripheral vision and reduces the conflicting visual cues that contribute to cybersickness. DOF blurring strategically applies blur to peripheral or less important areas of the virtual scene, a technique that mimics the human eye's natural focus. This creates a more comfortable visual experience by reducing the strain on eye movements caused by discrepancies between how humans and VR hardware process DOF (Biswas et al., 2024).

Rest frames is a strategy that introduces static elements within the virtual environment, such as grids, clouds, or even a virtual nose, which can provide a stable visual reference point to reduce sensory conflict. These rest frames, particularly those anchored to the user's head position, offer a sense of grounding in the virtual world, mitigating disorientation and nausea (Cao, Z., 2017). Optical flow is the pattern of visual motion in VR environments, which can have a significant role in cybersickness symptoms. VR designers can simplify the virtual environment to minimize optical flow complexity, as well as introducing reverse optical flow patterns that counteract the perceived motion, thereby reducing the discrepancy between visual and vestibular system inputs (Lou et al., 2022).

The VR headset is another significant factor in determining an individual’s extended use, and overall enjoyment, of the VR experience. High quality headsets have precise tracking systems that can effectively interpret the user’s hand and head movements, leading to accurate responses from the virtual system (Interaction Design Foundation, 2024). Furthermore, a VR headset can enhance the visual experience by utilizing high resolutions that reduce the visible lines between pixels. In addition to software considerations, the physical characteristics of a VR headset can have a considerable influence on user experience. A low quality headset can cause physical discomfort and fatigue during extended use, indirectly increasing the risk of cybersickness. Employing balanced weight distribution, adjustable straps, lightweight materials, ventilation, and appropriate padding can improve the comfort of a VR headset (Interaction Design Foundation, 2024). VR headsets that generate excessive heat or noise can distract the user and cause discomfort. However, well-designed headsets with adequate ventilation and noise-reducing features can minimize these distractions and contribute to a more comfortable and immersive VR experience.

While VR offers unique and exciting opportunities to transform entertainment in movies and sports, the challenge of mitigating cybersickness remains critical for broader adoption. Cybersickness stems from a combination of technical limitations, sensory conflicts, and individual susceptibilities, making it essential for VR designers to carefully balance immersion with comfort. VR designers can mitigate the effects of cybersickness by leveraging strategies such as FOV adjustments, DOF blurring, stabilization techniques, deliberate motion design, camera placement, as well as employing high-quality VR headsets. Overcoming these challenges will be essential to realizing VR's potential as a mainstream entertainment medium that combines immersion with accessibility.

References

Hamad, A., & Jia, B. (2022). How Virtual Reality Technology Has Changed Our Lives: An Overview of the Current and Potential Applications and Limitations. International journal of environmental research and public health, 19(18), 11278. https://doi.org/10.3390/ijerph191811278

Page, D., Lindeman, R. W., & Lukosch, S. (2023). Identifying Strategies to Mitigate Cybersickness in Virtual Reality Induced by Flying with an Interactive Travel Interface. Multimodal Technologies and Interaction, 7(5), 47-. https://doi.org/10.3390/mti7050047

Norouzi, N., Bruder, G., & Welch, G. (2018). Assessing vignetting as a means to reduce VR sickness during amplified head rotations. Proceedings of the 15th ACM Symposium on Applied Perception, 1–8. https://doi.org/10.1145/3225153.3225162

Davis, S., Nesbitt, K. & Nalivaiko, E. A systematic review of cybersickness. In Proceedings of the 2014 Conference on Interactive Entertainment, 1–9 (2014)

Kim, H., Kim, D. J., Chung, W. H., Park, K. A., Kim, J. D. K., Kim, D., Kim, K., & Jeon, H. J. (2021). Clinical predictors of cybersickness in virtual reality (VR) among highly stressed people. Scientific reports, 11(1), 12139. https://doi.org/10.1038/s41598-021-91573-w

Norouzi, N., Bruder, G., & Welch, G. (2018). Assessing vignetting as a means to reduce VR sickness during amplified head rotations. Proceedings of the 15th ACM Symposium on Applied Perception, 1–8. https://doi.org/10.1145/3225153.3225162

Stanney, K. M., Hale, K. S., Nahmens, I., & Kennedy, R. S. (2003). What to expect from immersive virtual environment exposure: influences of gender, body mass index, and past experience. Human factors, 45(3), 504–520. https://doi.org/10.1518/hfes.45.3.504.27254

Garrido, L. E., Frías-Hiciano, M., Moreno-Jiménez, M., Cruz, G. N., García-Batista, Z. E., Guerra-Peña, K., & Medrano, L. A. (2022). Focusing on cybersickness: pervasiveness, latent trajectories, susceptibility, and effects on the virtual reality experience. Virtual reality, 26(4), 1347–1371. https://doi.org/10.1007/s10055-022-00636-4

Caserman, P., Garcia-Agundez, A., Gámez Zerban, A., & Göbel, S. (2021). Cybersickness in current-generation virtual reality head-mounted displays: systematic review and outlook. Virtual Reality : The Journal of the Virtual Reality Society, 25(4), 1153–1170. https://doi.org/10.1007/s10055-021-00513-6

Biswas, N., Mukherjee, A., & Bhattacharya, S. (2024). “Are you feeling sick?” – A systematic literature review of cybersickness in virtual reality. ACM Computing Surveys, 56(11), 1–38. https://doi.org/10.1145/3670008

Gruber, M. E., Galliano, M. S., Brosnihan, A. P., & Hancock, P. A. (2023). The impact of camera usage and angle on perceptions of power during videoconferencing. Computers in Human Behavior Reports, 10, 100285-. https://doi.org/10.1016/j.chbr.2023.100285

Cao, Z. (2017). The Effect of Rest Frames on Simulator Sickness Reduction. ProQuest Dissertations & Theses.

Lou, R., Merienne, F., So, R. H. Y., Chan, T.-T., & Bechmann, D. (2022). Geometric simplification for reducing optic flow in VR. 2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), 682–685. https://doi.org/10.1109/ISMAR-Adjunct57072.2022.00142

Interaction Design Foundation - IxDF. (2024, January 10). What are VR Headsets?. Interaction Design Foundation. https://www.interaction-design.org/literature/topics/vr-headsets