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Cybersickness in Virtual Reality Education: A Review and Multidimensional Mitigation Strategies

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Abstract
Virtual Reality (VR) technology is reshaping the way humans interact with the digital world at an unprecedented rate. The purpose of this systematic review was to present the causes of cybersickness in VR education, assessment methods and their impact on learning outcomes, and suggestions for optimization. The study reveals that insufficient cognitive abilities exacerbate sensory conflicts between visual and vestibular systems, and individual differences also markedly influence susceptibility to cybersickness. Furthermore, VR device types differ in symptom severity, with HMDs' high immersion correlating with increased discomfort. By integrating subjective questionnaires and physiological metrics, the study proposes a multidimensional assessment framework. We suggest that measures such as optimizing device design, managing hours of use, and providing adaptive training may be effective in alleviating cybersickness symptoms.

***Keywords*:**
Virtual Reality; Cybersickness; VR Education; Individual Differences; Adaptive Design; STEAM Education; Cognitive Load; user experience

1. Introduction

1.1 Physical attribute

In VR education environments, cybersickness is closely linked to learners' cognitive abilities: weak spatial awareness exacerbates conflicts between virtual visual signals and vestibular spatial information[1-2]; scattered attention reduces focus on critical visual cues[3-4]; and insufficient multitasking ability overloads cognitive resources when navigating, interacting, and processing environmental feedback simultaneously[5-6], worsening discomfort and reducing operational accuracy.

The relationship between cybersickness and time typically involves the duration of exposure[7]. Intermittent use and adaptation periods [8] may influence symptom development. Time pressure in tasks[3][9] can affect users' cognitive load, indirectly contributing to motion sickness[10]. Learners with a history of motion sickness (such as motion sickness, seasickness, and airsickness) are more likely to have digital cybersickness in a VR environment, and the longer the history, the stronger the sensitivity [11-16].

Postural stability may affect students' motion control in VR[16-17]：vestibular-visual mismatch is the primary trigger [18-21], Vergence-Accommodation Conflict (VAC) plays a critical role[22-23], this sensory conflict is more easily perceived, leading to cybersickness. In VR applications that require body movement, such as virtual walking [24] and obstacle avoidance[25-26], learners with low postural stability may be distracted by difficulties in balance control, which indirectly increases cognitive load and discomfort. Interaction preferences are due to mismatched motion and visual feedback [27], while experienced learners reduce symptom sensitivity through vestibular adaptation. Novices or intermittent users, lacking adaptation and experience[28][24] are more prone to cognitive overload and sensory mismatch in complex interactions.

1.2 Individual differences

The more immersive students are in a VR environment, the more engaged and motivated they are to learn [29]. The experience of cybersickness varies significantly between individuals, and there is a need to incorporate individual differences into VR research [30]. A relationship exists between age and motion sickness. Age and cybersickness susceptibility are related to each other. Children between 2 and 12 may show higher sensitivity, but this sensitivity tends to decline in early adulthood[31]. Young people tend to adapt better to virtual reality due to greater exposure to digital environments [32]. In terms of gender, women are generally considered to be more prone to a motion sickness response than men, which may be related to their smaller pupil spacing, hormonal changes during menstruation, and other physiological characteristics [33][20]. However, other studies have shown no significant differences between male and female participants in the presence and severity of cybersickness.

Racial factors may also be related to cybersickness[31], with Asians being more sensitive to VR-induced motion sickness compared to other ethnic groups. Asians may inherit lower thresholds and sensitivity to feedback from one or more physiological stimuli, such as greater sensitivity to changes in osmolality, stress hormones, or blood pressure[34]. The study found no significant differences in gastric response and symptom reporting between European Americans and African Americans, but Chinese subjects showed more severe disturbances in gastric motility and more intense self-reported symptoms of cybersickness, showing significant racial differences [29].

1.3 VR systems

VR has received attention for its ability to enhance learner motivation, engagement, and learning outcomes compared to traditional learning methods [35-43]. However, the relationship between cybersickness and the type of VR system used is an important consideration in the design of immersive educational environments.

From a technical perspective, VR systems can be categorized into low immersion platforms (larger screens VR) and high immersion platforms (HMD). There are significant differences between the two in terms of how the immersive experience is constructed and cybersickness impact on the learner. Low immersion VR relies heavily on virtual activities and interaction design to enhance engagement. larger screens VR systems rely on traditional displays and limited input devices and typically provide the user with active control of movement, so there is less or predictable conflict between visual and vestibular perception, thus triggering less cybersickness [36]. Although the immersion and interactivity of such systems is relatively limited[37], they would be more suitable for younger learners, beginners, or users with a history of motion sickness.

In contrast, highly immersive VR creates a stronger sense of presence and “immersive” experience on the physical level through spatial perception and sensory deception, even if the environment is smaller or less social[38]. VR systems based on head mounted display (HMD)provide richer sensory immersion. But these features tend to increase the risk of cybersickness especially when there is a delay between the user's head movements and visual updates [39-40], or when there are inconsistencies between visual and vestibular inputs[41]. This study [42] suggests that highly immersive VR users can interact more easily through natural user interfaces, which also provides more opportunities for experiential learning. However, immersive experiences are likely to be more engaging and impactful to users [43]. All the detailed reasons can be seen directly in Figure 1.

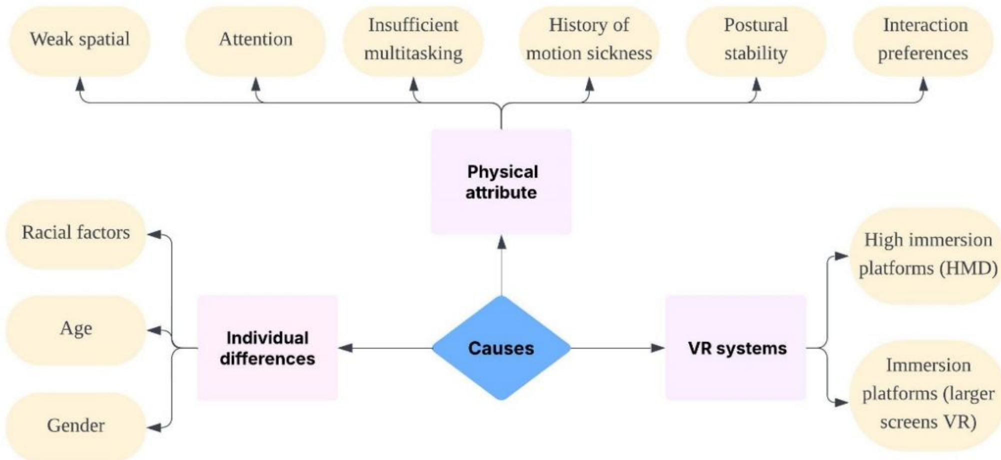

Fig 1: Causes of cybersickness

2. Method

We began the preparation phase by identifying the research questions, the focus of the review, the search strategy, and the relevant inclusion and exclusion criteria. The study commenced with a structured preparatory phase to define the scope and rigor of the systematic review. First, we formulated three core research questions to guide the investigation:

-How do VR system designs (e.g., HMDs, CAVEs) influence cybersickness severity in educational contexts?

-What pedagogical and technological strategies effectively mitigate cybersickness while preserving learning outcomes?

-How do individual differences (e.g., age, prior VR exposure) modulate user experience in immersive education?

Based on our initial survey of the literature, we identified keywords: virtual reality, cybersickness, HMD, education, immersive learning, and user experience were used to synthesize the research. To ensure comprehensive coverage, a multi-database search strategy was implemented. We started out using Google Scholar for our searches and then expanded to other databases (Scopus, Web of Science, IEEE Xplore) as well as search engines of publishers (e.g. Springer, Taylor and Francis, MDPI, Frontiers).
The screening goes through two stages:

Stage 1 (Title/Abstract Screening):
-Inclusion: Empirical or theoretical studies addressing VR, cybersickness, and education; English language; peer-reviewed or reputable conference publications.
-Exclusion: Non-educational applications; non-English texts; opinion pieces.

Stage 2 (Full-Text Evaluation):
-Focus on studies reporting quantitative metrics (e.g., SSQ scores, task performance) and Relevance of the full-text content to our topic

From an initial pool of 256 articles, 73 met the criteria after title/abstract screening, spanning from 1993 to 2025. A thematic analysis of the selected literature is then conducted to compare how different VR systems affect user experience in an educational context.

3. VR education current situation

STEAM education is an interdisciplinary educational model that integrates science, technology, engineering, arts and mathematics. VR technology offers an innovative way to teach STEAM education through immersive experiences and interactivity. Based on the closely intertwined but differently targeted education phases K-12(primary and secondary) and higher education (HE).

Despite the transformative potential of VR in STEAM education, but As the core experience of VR teaching, CS can be one of the key factors affecting the usability and learning experience of VR teaching[44-45]. In educational Settings, prolonged exposure to immersive environments or complex interactions can exacerbate symptoms such as dizziness, nausea, and disorientation. These symptoms not only disrupt the learning experience but may also negatively impact students' cognitive performance and overall engagement with VR-based educational content. Task workload can also have an impact on cybersickness [3][46], with static or low-motion scenes showing a reduced incidence of symptoms, but careful interface design is needed to avoid visual fatigue [22][47]. Complex engineering tasks that require multitasking can lead to cognitive overload [48], which can exacerbate the severity of motion sickness [14][49].

Given the pervasive impact of cybersickness on VR-enabled STEAM education, systematic evaluation and mitigation of these symptoms become imperative to ensure both pedagogical efficacy and user comfort. We highlight how cognitive demands and disciplinary-specific interactions exacerbate cybersickness, a critical next step lies in quantifying its severity and identifying personalized solutions.

4. Cybersickness evaluation tool

4.1 Questionnaire

Currently, the assessment of motion sickness relies mainly on the task load index, the Simulation Task Load Index (SIM-TLX), cybersickness Questionnaire (CSQ), Virtual Reality Sickness Questionnaire (VRSQ) [50]. Simulator sickness questionnaire（SSQ） was proposed by Kennedy et al. [51] and relies on the user's self-reported level of certainty. Using the SSQ to measure levels of motion sickness separately before and after immersion has shown that VR environments typically significantly enhance SSQ scores, especially when using head-mounted display devices (HMDs) [52-53]. Correlational analyses of SSQ results with individual subjective experiences such as presence, immersion, and learning performance have found that high SSQ scores tend to impair learning experiences and outcomes[54-55]. However, SSQ scores can be reduced to some extent by optimizing the VR system design, thereby mitigating motion sickness [53].

4.2 Physiological survey

Physiological data [56] provide a more objective and continuous test for the assessment of virtual reality motion sickness, compensating to some extent for the lack of subjective questionnaire analysis. Keshavarz et al. [57] train a model that predicts the user's level of dizziness based on a variety of physiological data, pointing to a correlation between heart rate and cybersickness. Existing studies on blink frequency and screen sickness also reveal a positive correlation between SSQ scores and blinks[58-59]. This paper builds on existing research using a variety of virtual reality motion sickness relief methods to capture heart rate[60], eye tracking[61], respiration rate[56][62],electrogastrogram (EGG)[63-64], even temperature(65) and SSQ scale results as an assessment of the level of motion sickness.

4. Influence

In general, there is no significant difference in the level of cybersickness symptoms experienced by individuals using cave automatic virtual environments (CAVEs) or HMDs VR systems[66]; based on comparing the two popular VR systems now available in the field of teaching and learning, HDM-induced screen-sickness cybersickness is much more severe when compared with the large screens VR system [67]. The direct perceptual input to both VR systems is dominated by visually displayed relative motion stimuli, so the main symptomatic manifestations are also related to the individual's visual system and orientation perception[68-69]. This discomfort is a negative influence on VR experience. Cybersickness is strongly associated with changes in skin temperature-regulated vascular tone. Cybersickness induced by visual factors leads to an increase in heart rate, the magnitude of which is highly correlated with the dimension of nausea[70]. The physical discomfort caused by cybersickness can result in a slight decrease in cognitive performance [71] and has a negative impact on the enjoyment of VR games and the learning outcomes of VR training[72].

Thus, it can be concluded that in VR teaching activities, cybersickness may be a negative factor affecting learners' learning experience and learning efficiency, which may cause learners' perception of the ease of use of VR teaching and lower learning satisfaction during the learning process. The goal of achieving presence has been regarded as a defining aspect of a successful VR experience[44][73]. Cybersickness and presence experiences have a complex relationship. On the one hand, as cybersickness symptoms deepen, the physical discomfort experienced by the user affects the sense of presence and immersion, but on the other hand, highly realistic and detailed VR environments tend to be highly immersive but are also more likely to induce cybersickness symptoms. Scenes with high levels of visual detail provide rich visual stimuli, and individuals need to allocate more cognitive resources to process this information, thus individuals lack sufficient cognitive resources to process conflicting information between the senses. Cognitive overload of the brain may be the main reason why individuals are more likely to induce cybersickness in VR scenes with high richness, realism, or task complexity. In addition, the physical discomfort that users experience as a result of being in a deepened state during prolonged learning activities may reduce immersion and presence [44].

5. Future strategies

VR technology is used to support teaching and learning practices, and its use as a platform for teaching and learning needs to ensure that the novelty of the system does not overshadow its educational purpose, and that the design of the teaching and learning process is conceived with a clear understanding of the target audience, the subject matter, and the methodology to be used to determine whether or not to adopt a VR system. Learners will exhibit physiological and psychological feedback such as emotions, beliefs, preferences, expectations, behaviours, and feelings of accomplishment before, during, and after using a VR product. Only by focusing on the learner as the starting point and ultimate goal of VR teaching design can excellent VR teaching products be designed. We have developed proposals in five directions, as detailed in Figure 2.

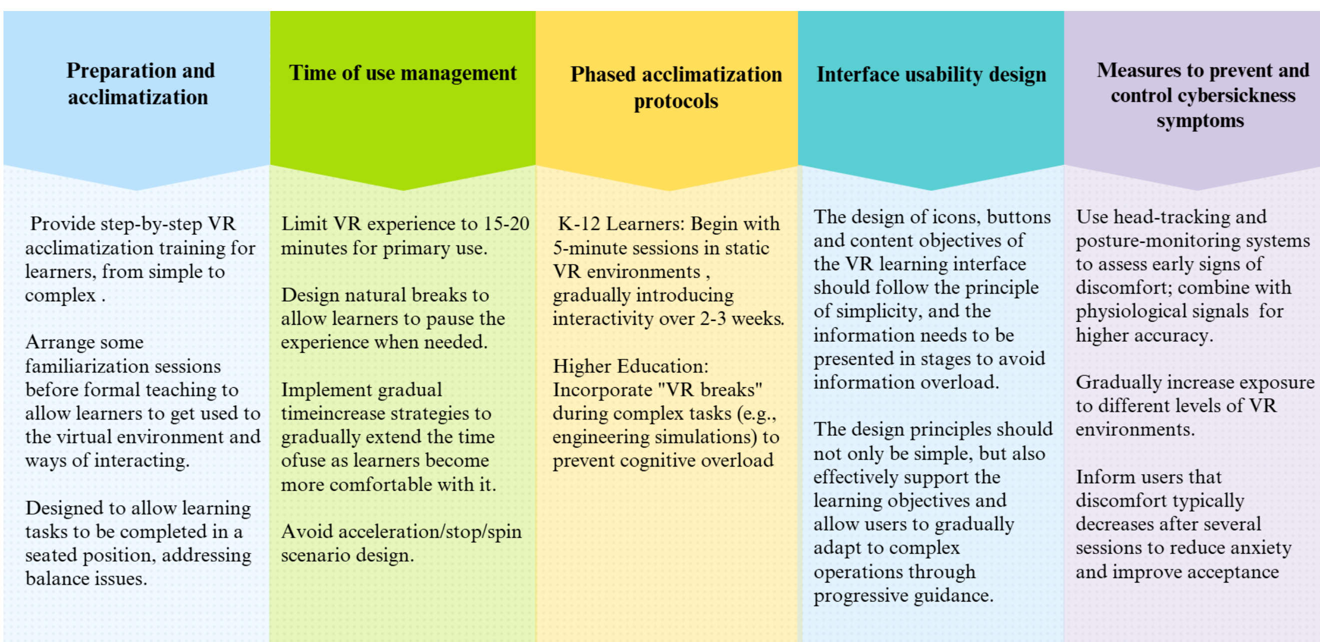

Fig 2: Multidimensional Optimization and Cybersickness Mitigation Strategies in VR Education

6. Conclusion

A review of the causes, assessment and optimization strategies of motion sickness in VR education is presented in this paper. The study shows that motion sickness stems from visual-vestibular conflicts and convergence regulation conflicts triggered by cognitive deficiencies, with individual differences significantly affecting sensitivity, and highly immersive devices exacerbating symptoms due to delays and sensory dislocations. A multidimensional assessment framework that combines subjective scales and physiological indicators can improve diagnostic objectivity. In the future, we need to focus on learner-centered design and suggest optimizing device design to balance immersion and comfort, adapting to training in stages, limiting the duration of a single use, simplifying the interface to reduce cognitive load, and paying attention to the cognitive effects of long-term exposure to promote the sustainable development of VR technology in the field of education.

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