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Examining the Relationship Between Cybersickness, Postural Instability and Its Impact on Virtual Reality Experience

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Abstract:
This study aimed to investigate in the gaming population, if Immersive Virtual Reality (VR) induces cybersickness and impacts equilibrium coordination in gamers, which has become a negative consequence of degrading the interface for VR users. Various abnormalities can cause quantifiable changes in body awareness when donning a Head Mounted Display (HMD) in a Virtual Environment (VE), which VR headsets provide to match the actual world and allow users to have a range of experiences. The research used a cross-sectional observational analysis and recruited 40 subjects in and around bengaluru, based on selection criteria, with the intervention lasting 6 months. The after-effects of the virtual environment were evaluated using a Simulator Sickness Questionnaire, which holds a single period for measuring motion sickness. Equilibrium tests were done thrice, before gaming, at the exit, and after 10 mins. Statistical analyses were performed using paired t-tests. The results showed that the participants experienced cybersickness, as indicated by their Simulator Sickness Questionnaire (SSQ) scores and t-value. The study also found that the participants' average equilibrium coordination deteriorated before gaming to exit, and improved from exit, indicating a stabilizing condition. However, further research is needed to determine whether cybersickness affects equilibrium coordination. Although virtual reality in video games is still developing, integrating gameplay action into the VR experience will necessitate significant study and development.

Keywords: Virtual reality, postural instability, Simulator sickness questionnaire (SSQ), equilibrium coordination.

INTRODUCTION

Virtual reality (VR) technology has rapidly advanced in recent years, providing users with immersive and realistic experiences in various domains. From gaming and entertainment to healthcare and education, VR technology has been widely used to create interactive and engaging environments that simulate real-world experiences. However, the use of VR technology has been associated with the phenomenon of cybersickness, which refers to a range of symptoms that can occur when using VR devices. These symptoms include nausea, headache, dizziness, disorientation, and eyestrain, among others. Cybersickness can have a significant impact on the usability and safety of VR technology, particularly in situations that require precise control of movement and balance. In recent years, researchers have been investigating the factors that contribute to cybersickness and its effects on various aspects of human behavior, including equilibrium coordination. Equilibrium coordination refers to the ability to maintain postural stability and balance during various movements, such as walking, standing, or reaching. This ability is critical for daily activities and can have a significant impact on overall quality of life. Therefore, it is important to understand how cybersickness affects equilibrium coordination and how this can be mitigated or prevented

Cybersickness is a relatively new phenomenon that has emerged with the increasing use of VR technology. It is often described as a feeling of discomfort or disorientation that can occur when using VR devices. The symptoms of cybersickness are similar to those of motion sickness, which occurs when the brain receives conflicting signals from the visual and vestibular systems. In the case of cybersickness, the visual system is presented with a virtual environment that is often in conflict with the vestibular system's perception of the user's actual motion or position. This conflict can cause the user to experience nausea, headache, dizziness, and other symptoms. There are several factors that can contribute to the onset of cybersickness. One of the main factors is the design of the VR environment. VR environments that are visually complex or that contain rapid or unexpected movements are more likely to induce cybersickness. The quality of the VR device itself can also be a factor, as lower-quality devices can produce a lower frame rate or resolution, which can contribute to motion sickness. In addition, individual factors such as age, gender, and prior experience with VR can also influence susceptibility to cybersickness.

The impact of cybersickness on equilibrium coordination has been the focus of several studies in recent years. Researchers have used a range of techniques to investigate the effects of cybersickness on postural stability, gait patterns, and other related outcomes.Several studies have investigated the effects of cybersickness on postural stability, which is the ability to maintain balance while standing or moving. One study found that individuals who experienced cybersickness while using VR technology also experienced a decrease in postural stability compared to those who did not experience cybersickness (1). Similarly, another study found that individuals who experienced cybersickness during VR exposure had a reduced ability to maintain postural stability during quiet standing (2). These findings suggest that cybersickness can have a negative impact on postural stability, which can have implications for everyday activities that require balance and stability.Other studies have investigated the effects of cybersickness on gait patterns, which is the way individuals walk or move. One study found that individuals who experienced cybersickness during VR exposure had a slower walking speed and a longer stride length compared to those who did not experience cybersickness [3]. Similarly, another study found that individuals who experienced cybersickness while using VR technology had alterations in their gait patterns, including a reduction in stride length and an increase in step time variability [4]. These findings suggest that cybersickness can have a negative impact on gait patterns, which can have implications for everyday activities such as walking and running.In addition to postural stability and gait patterns, researchers have also investigated the effects of cybersickness on other measures of equilibrium coordination. For example, one study found that individuals who experienced cybersickness during VR exposure had a decreased ability to maintain balance during a tandem stance task [5]. Similarly, another study found that individuals who experienced cybersickness had a reduced ability to maintain balance during a Romberg test, which measures the ability to maintain balance while standing with eyes closed [6]. These findings suggest that cybersickness can have a broad impact on various aspects of equilibrium coordination, including postural stability, gait patterns, and balance control.

NEED OF THE STUDY

To Understanding the relationship between cybersickness and postural instability is important for several reasons. First, it can help to identify individuals who may be particularly susceptible to these negative side effects, allowing for targeted interventions or modifications to VR experiences to minimize the risk of cybersickness. Second, it can help to inform the design of future VR technologies, with a focus on minimizing the potential for cybersickness and postural

instability. By examining the relationship between cybersickness and postural instability, researchers can gain a better understanding of how these factors interact to impact the VR experience. This knowledge can help to improve the overall safety and usability of VR technology, ensuring that it remains an effective and enjoyable tool for entertainment, education, and other applications.

OBJECTIVE

1. 1.To measure the severity of cybersickness symptoms in participants who use VR technology.
2. To assess postural stability in participants before and after exposure to a VR environment.
3. To examine the relationship between cybersickness and postural instability, and whether individuals who experience cybersickness also show increased postural instability.
4. To investigate the impact of postural instability on the overall VR experience, including factors such as immersion, presence, and enjoyment.
5. To identify potential factors that may contribute to cybersickness and postural instability inVR, such as age, gender, and prior experience with VR technology.

METHODOLOGY

This observational study takes place over 6 months with a straightforward random sampling evaluation. This study was conducted in and around Bengaluru, Karnataka, India. The sample size was calculated by G*power analysis, which figures to be 40, the participants chosen for this study aged 18 to 27 years were undergraduates and postgraduate students of Dayananda Sagar University. Each participant received a 15-minute in-person explanation of the study's use of various VEs and any potential risks associated with using virtual reality. A consent form was signed for the experiment. The study's participants were required to be physically fit and not involved in activities such as gymnastics or ballet that involve balance control. Additionally, the study excluded individuals with a history of seizures, migraines, or lower limb musculoskeletal injuries, likely to minimize the impact of these factors on the study's results.

Virtual reality hardware: The VR headset used for this experiment features a single fast-switch LCD with a resolution of 1832x1920 pixels per eye and a 72 Hz refresh rate, as well as a default SDK color space with primary colors of red, green, blue, and white. It is powered by a Qualcomm Snapdragon XR2 Platform and has a 3 preset IPD adjustment while weighing 503 grams (17.7 ounces). The headset also utilizes "next-generation" lens technology.

Virtual environment: This project uses an interactive and immersive virtual reality game, specifically "Sports Scramble" for 20 minutes and "Roller Coaster" for 25 minutes, as the virtual environment. While using the game, the user can freely rotate their head to view the environment from different angles, but they are limited to moving forward on a predetermined path. To evaluate the patient's condition, the simulator sickness questionnaire has been employed [1]

The proposed SSQ is a well-established measurement for assessing simulator illness, which is commonly used in virtual reality studies. It is divided into three categories: nausea, oculomotor,12 and disorientation, and is employed to assess and minimize simulator sickness, as well as to investigate any significant impact on it. The reason for selecting this questionnaire for the study is due to its simplicity and convenience, time efficiency, lack of reliance on costly technology, and its psychometric properties, which include reliability (0.94) and validity (0.805). Additionally, equilibrium tests such as standing on one foot, tandem standing, Romberg test, sharpened Romberg test, and tandem walking were also conducted. The summary of the data collection procedure is presented in Figure 1, which involved the participation of 40 individuals comprising both men and women. Each participant was given a 15-minute face-to-face session to understand the nature of the virtual environments (VEs) utilized in the study, as well as the potential adverse effects of VR. They were required to sign consent forms before the experiment commenced. Subsequently, each participant was provided with an Oculus Quest HMD device and spent 45 minutes playing VR games. Coordination tests for standing and walking were conducted after the VR immersion session. After completing these tests, participants were instructed to rest for 10 minutes while the SSQ was administered to assess any symptoms of cybersickness they experienced. Following the 10-minute rest period, the coordination tests were re-evaluated.

RESULTS

Table 1 displays the results of the mean age of participants. The test revealed that the average age of the participants was 22.8± 3.1 years, with the age range falling between 18 to 27 years old. Of the 40 participants, 11 (27.5%) were aged between 18 to 20 years old, while 14 participants (35%) were aged between 21 to 23 years old. Additionally, 15 participants (37.5%) were aged between 24 to 27 years old.

Table 1

Age group in years	No of patients	Percentage (%)
18-20 yrs	11	27.5
21-23 yrs	14	35
24-27 yrs	15	37.5
Total	40	100
Mean±SD	22.8±3.1	

Table 2 : Comparison of equilibrium test before gaming and at exit, using students paired t-test

Test	Before gaming	At Exit	Mean difference	t value
Standing in one foot	6.90±0.75	2.42±0.4	4.48±0.80	34.6,p=0.0001,S
Tandem standing	7.17±1.3	2.58±0.9	4.58±1.4	15.43,p=0.0001,S
Romberg test	5.95±0.49	2.270±0.5	3.68±0.70	31.6,p=0.0001, S
Tandem walking	6.15±0.58	2.272±0.5	3.88±0.8	30.6,p=0.0001,S

Table 2 presents the results of a paired t-test comparing equilibrium tests before gaming and at exit. The mean time (± standard deviation) for standing on one foot, tandem standing, Romberg test, and tandem walking before gaming was 6.90 ± 0.75 seconds, 7.17 ± 1.3 seconds, 5.95 ±0.49 seconds, and 6.15 ± 0.58 seconds, respectively. At exit, the mean times were 2.42 ± 0.4 seconds, 2.58 ± 0.9 seconds, 2.270 ± 0.5 seconds, and 2.272 ± 0.5 seconds, respectively. The mean differences were 4.48 ± 0.80 seconds, 4.58

± 1.4 seconds, 3.68 ± 0.70 seconds, and 3.88 ±0.8 seconds, respectively. The t-values for each test were all highly significant with p-values of 0.0001 and effect sizes (S) ranging from high to very high, indicating significant differences between the two tests.

Table 3: Comparison of equilibrium test at exit and after 10 mins, using students paired t-test

Test	At Exit	After 10 mins	Mean difference	t value
Standing in one foot	2.42±0.4	3.44±0.5	1.02±0.5	8.2, p=0.0001, S
Tandem standing	2.58±0.9	3.47±0.6	0.88±0.6	5.09, p=0.0001, S
Romberg test	2.270±0.5	2.7±0.4	0.51±0.6	5.085, p=0.0001, S
Tandem walking	2.272±0.5	3.44±0.6	1.1±0.7	9.12, p=0.0001, S
Test	At Exit	After 10 mins	Mean difference	t value
Standing in one foot	2.42±0.4	3.44±0.5	1.02±0.5	8.2, p=0.0001, S
Tandem standing	2.58±0.9	3.47±0.6	0.88±0.6	5.09, p=0.0001, S
Romberg test	2.270±0.5	2.7±0.4	0.51±0.6	5.085, p=0.0001, S
Tandem walking	2.272±0.5	3.44±0.6	1.1±0.7	9.12, p=0.0001, S

Table 3 compares the equilibrium test results at exit and after 10 minutes using a paired t-test. Standing on one foot at exit had a mean time of 2.42 ± 0.4 seconds, while after 10 minutes it was 3.44 ± 0.5 seconds, with a mean difference of 1.02 ± 0.5 seconds (t-value = 8.2, p-value = 0.0001, S). Tandem standing had a mean time of 2.58 ± 0.9 seconds at exit and 3.47 ± 0.6 seconds after 10 minutes, with a mean difference of 0.88 ± 0.6 seconds (t-value = 5.09, p-value = 0.0001, S). The Romberg test had a mean time of 2.27 ± 0.5 seconds at exit and 2.7 ± 0.4 seconds after 10 minutes, with a mean difference of 0.51 ± 0.6 seconds (t-value = 5.085, p-value= 0.0001, S). Finally, tandem walking had a mean time of 2.272 ± 0.5 seconds at exit and 3.44 ±0.6 seconds after 10 minutes, with a mean difference of 1.1 ± 0.7 seconds (t-value = 9.12, p- value = 0.0001, S).The significant differences observed in all equilibrium tests (standing on one foot, tandem standing, Romberg test, and tandem walking) between the two time points (at exit and after 10 minutes) suggest that playing video games can have a short-term negative impact on a person's ability to maintain balance and posture. The high effect sizes (S) reported in each testindicate that the observed differences are not due to chance alone, but rather due to the gaming experience.

All these t-values suggest that the experimental value is in the rejection region of the Gaussian distribution curve for significance level 0.0005, indicating that the null hypothesis can be rejected and the alternate hypothesis can be accepted. Therefore, based on the results, we can conclude that the participants experienced cybersickness, with a deterioration in their average value from before gaming to exit, but an improvement from exit. This suggests that their condition is stabilizing.

It is important to note, however, that the study only evaluated short-term effects, and it is unclear if prolonged gaming would have a more lasting impact on equilibrium. To obtain more conclusive evidence regarding whether cybersickness causes postural instability and affects coordination skills, it is recommended to administer the test 30 minutes to 1 hour after the initial assessment. This will allow for a better evaluation of the participant's health status.

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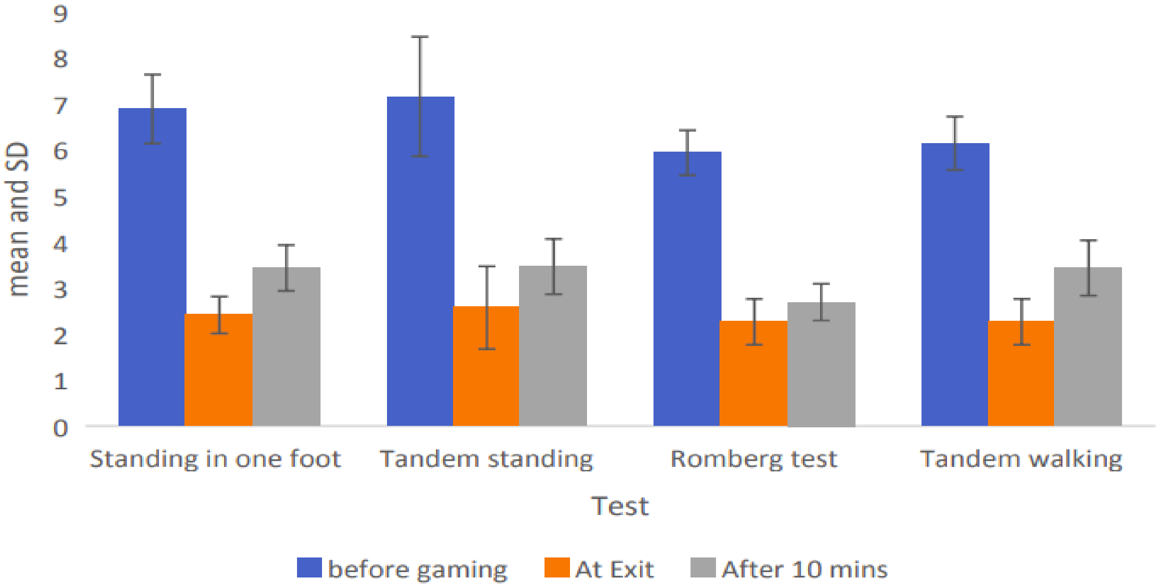
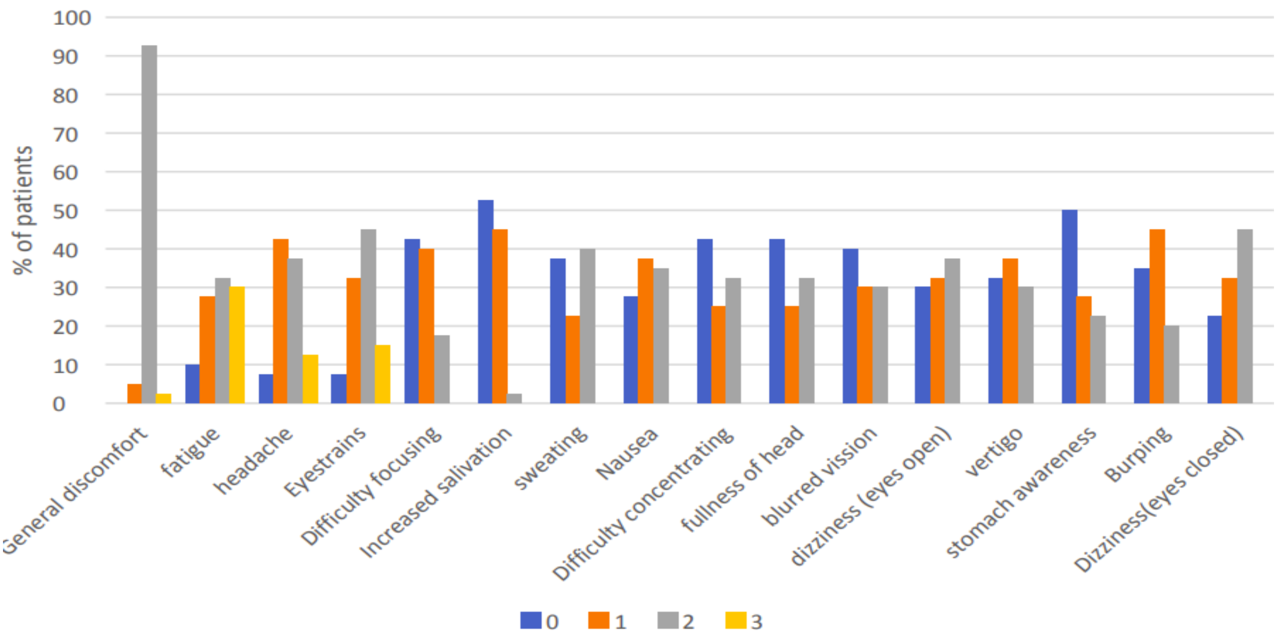
Figure 1 :Comparison of equilibrium test before gaming, at exit and after 10 mins.



The SSQ components for a sample of 40 individuals were recorded, and the distribution of the patients and their percentage of experiencing "none, slight, moderate, and severe" levels for each component was depicted in Figure 3. The SSQ components included General discomfort, Fatigue, Headache, Eye strain, Difficulty focusing, Salivation increasing, Sweating, Nausea, Difficulty concentrating, Fullness of the head, Blurred vision, Dizziness and eye open, Dizziness and eye close, Vertigo, Stomach awareness, and Burping.

Figure 2:The distribution of patients is categorized based on their Simulator Sickness Questionnaire (SSQ) score.



DISCUSSION

The business of HMD is flourishing and caters to a wide range of users. The purpose of the studywas to see how cybersickness affects equilibrium when utilized with HMD in gamers. Various studies have been undertaken which concluded that postural instability is one of the cybersickness effects in gamers and very little data was found regarding coordination and effects of cybersickness on coordination. Thus, the need was felt to conduct the current study tofind if immersive VR induces cybersickness and impacts equilibrium coordination.

The evidence suggests that exposure to VR environments can induce cybersickness, which in turn can lead to postural instability and decreased balance control. This effect has been observed in healthy individuals, older adults, patients with chronic neck pain, and individuals with MS. Keshavarz and Hecht (2011) conducted a study on the effects of virtual reality exposure on postural stability(12) . They found that participants who experienced cybersickness had significantly greater postural sway compared to those who did not experience cybersickness. Kolasinski et al. (2018) conducted a study on the effects of virtual reality exposure on postural stability in Parkinson's disease patients. They found that cybersickness significantly increased postural sway in these patients (16). Weech et al. (2019) investigated the relationship between cybersickness and postural instability in a study using a virtual environment. They found that participants who experienced cybersickness had increased postural sway compared to those who did not experience cybersickness (38). Chardonnet et al. (2018) conducted a study on the effects of cybersickness on postural stability during a simulated driving task. They found that participants who experienced cybersickness had significantly increased postural sway compared to those who did not experience cybersickness (3). Palmisano et al. (2015) conducted a study on the effects of cybersickness on postural stability using a virtual rollercoaster simulator. They found that participants who experienced cybersickness had increased postural sway compared to those who did not did not experience cybersickness (15).Kizilcec et al. (2016) investigated the effects of VR exposure on gait stability and found that participants who experienced cybersickness had increased step time variability and reduced stride length compared to those who did not experience cybersickness. The authors suggested that cybersickness may affect the somatosensory system, leading to impaired gait stability(18). Similarly, a study by Kim et al. (2018) investigated the effects of VR exposure on trunk control and found that participants who experienced cybersickness had reduced trunk stability comparedto those who did not experience cybersickness. The authors suggested that cybersickness may affect the visual and vestibular systems, leading to impaired trunk control.Weech et al. (2019) investigated the effects of VR exposure on balance control in older adults and found that cybersickness significantly impaired postural stability and increased the risk of falls (17). The authors suggested that cybersickness may affect the vestibular and somatosensory systems, leading to impaired balance control.Overall, these studies suggest that cybersickness can have a negative impact on equilibrium coordination and postural stability. While the underlying mechanisms are not fully understood, it is likely that cybersickness affects the vestibular system, which is critical for maintaining balance. Further research is needed to fully understand the relationship between cybersickness and equilibrium coordination, as well as to develop effective interventions to mitigate the negative effects of cybersickness on postural stability.

A Simulator sickness questionnaire is used to understand the participant's condition. Similar studies that used simulator sickness questionnaires are, Kennedy et al. (2003) This study investigated the effects of a virtual environment on postural stability and cybersickness in healthy adults. The SSQ was used to measure the severity of cybersickness symptoms experienced by participants after they completed a virtual environment task. The results showed a significant increase in SSQ scores among those who experienced cybersickness compared to those who did not, suggesting that cybersickness may affect postural stability(8). Lin et al. (2002) This study explored the relationship between simulator sickness and postural stability in a virtualenvironment. The SSQ was used to measure the severity of cybersickness symptoms experiencedby participants. The results showed that those who experienced more severe cybersickness symptoms had decreased postural stability compared to those who did not experience cybersickness [(13)]. Keshavarz and Hecht (2011) In this study, the SSQ was used to measure the severity of cybersickness symptoms experienced by participants after playing a driving simulation game. The results showed that the severity of cybersickness symptoms was positivelycorrelated with postural instability, suggesting that cybersickness may have a negative impact onpostural stability [(12)]. Kim et al. (2018), This study investigated the effects of virtual reality exposureon postural stability and cybersickness in healthy adults. The SSQ was used to measure the severity of cybersickness symptoms experienced by participants. The results showed that the severity of cybersickness symptoms was significantly correlated with postural instability, indicating that cybersickness may affect postural stability [(4)]. Lee et al. (2016) This study examinedthe effects of cybersickness on postural stability in a virtual environment. The SSQ was used to assess the severity of cybersickness symptoms experienced by participants. The results showed that those who experienced more severe cybersickness symptoms had decreased postural stability compared to those who did not experience cybersickness [(11)]. In summary, these studies suggest that there is a correlation between cybersickness and postural instability, as measured by the SSQ. Cybersickness symptoms may affect postural stability and increase the risk of falls, especially in virtual environments where visual and vestibular cues are not consistent with physical movement.The cause of cyber sickness, which refers to the symptoms of nausea, dizziness, and disorientation that some people experience while using virtual reality or other immersivetechnologies, is not yet fully understood. More research is needed to determine the underlying factors that contribute to this phenomenon.

CONCLUSION

The SSQ, which is recognized as the leading tool for assessing cybersickness symptoms following virtual reality exposure, was evaluated, and implemented in the current study as a screening tool after immersive gamification. The study analyzed the standing and walking equilibrium coordination assessments in a virtual environment. The study's results indicate that:

1) the SSQ can be utilized to assess the after-effects of stimulation, 2) cybersickness negatively affects equilibrium, and 3) deterioration in their average value from before gaming to exit, but an improvement from the exit. This suggests that their condition is stabilizing which can be concluded as the altered equilibrium is a short-term effect. These findings suggest that the VR headset induces motion sickness-like responses and destabilizes equilibrium.

However, the limited number of participants and the specific tasks performed during the experiment restrict generalization. The study's assessment only covered short-term effects, leaving it uncertain whether extended gaming has a more persistent impact on equilibrium. To establish more definitive evidence regarding the connection between cybersickness and postural instability or coordination skills, it is advised to conduct the test between 30 minutes to 1 hour following the initial evaluation. This timeframe would enable a more comprehensive assessment of the participant's health status. To gain a deeper understanding of sickness symptoms and equilibrium measures, additional tests and discussions are required.

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