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A Study on the Correlation between VR Content and Cybersickness

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Abstract. This study investigated cybersickness severity across three virtual reality contents designed to induce varying degrees of visual-vestibular mismatch. Fifty participants experienced low, moderate, and high sensory mismatch contents using a head-mounted display. Cybersickness was quantified through the Simulator Sickness Questionnaire. Results demonstrated strong positive correlations between disorientation and overall sickness for all contents. The moderate mismatch content elicited the highest sickness ratings and correlations with motion sickness susceptibility, likely due to ambulatory movement illusions. The sensory conflict theory appears relevant to VR designs inducing vestibular disturbances through visual scene motion. Further inquiry with larger samples and objective sickness measures is warranted.

Keywords: virtual reality, content, cybersickness, hardware

1. Introduction

The virtual reality market is evolving rapidly through the convergence of technology and content and is characterized by the need to provide users with a sense of immersion and reality in a relatively short time. Virtual Reality is a tool that allows users to interact with objects through a computer for a realistic experience. Virtual Reality is a compound word of virtual and reality, which means that a situation is created with artificial technology inside a cyberspace built on a computer. In other words, Virtual Reality is a device that reproduces a situation like reality in a virtual space and allows users to experience it indirectly through interaction with human sensory organs. It also refers to things that can refer to things that are similar to real life situations but are not real, and both the background and environment are composed of virtual images rather than reality (Davis et al., 2014). In Virtual Reality, technology implements a virtual space, not a real one. It is technically an interface between people and media that an interface between people and media that interact with a virtual environment in real time in a computer-generated virtual reality, where hardware that provides users with the illusion of physical presence in the environment is used (Bric et al., 2016).

In general, Virtual Reality programs are used in various fields such as military, medical, education, entertainment, and games with the advantage of experiencing a virtual reality three-dimensional environment using head-mounted devices (HMDs 3D) and realizing reality.

In addition, in recent years, it has been developed with various programs such as education for the public, and it is also an area that has expandability in more diverse fields of daily life in the future (Chang et al., 2013). The initial virtual reality market was difficult to access with expensive equipment, but the price range has fallen significantly due to recent technological improvements and the spread of equipment, and the accessibility of the public has improved significantly with the emergence of much low-cost virtual reality equipment (Jung et al., 2014).

As such, virtual reality is emerging as an influential topic in the IT industry under rapid technological advancement, and as many companies distribute low-cost, high-performance head-mounted displays, the public's interest and accessibility are increasing, and the demand for virtual reality content is continuously increasing. However, even though various virtual reality contents are available, cyber sickness, which is caused by an imbalance between the body's movement and the brain's process of recognizing information from images, still exists. In addition, cybersickness, a symptom experienced by more than 60% of users when using virtual reality, continues to be a problem that hinders users' immersion and leads to negative experiences (Keshavarz et al., 2014). The virtual reality industry and academics studying virtual reality (VR) have been conducting a lot of research as a preliminary problem to be solved, and previous studies have shown that identifying the factors of cybersickness is an essential task the virtual reality industry to keep thriving (Koo & Kim 2019). One of the factors that can disrupt a user's sense of security in a virtual reality environment is motion sickness, and motion sickness that occurs when experiencing a virtual reality environment is called cyber sickness.

Cyber sickness refers to symptoms similar to motion sickness when using a virtual reality device. The usual manifestations are nausea and vomiting. These symptoms are similar to motion sickness in 3D movies and TV (Nesbitt et al, 2017), but cyber sickness that occurs while experiencing virtual reality is different from simulator sickness. Cybersickness and simulator sickness are subtypes of motion sickness that occur when experiencing virtual reality environments (Palmisano et al., 2017; Moon et al., 2021).

Simulator sickness refers to side effects experiences that occur during and after exposure to simulator virtual environments such as military training and aircraft control, and cyber sickness occurs while experiencing virtual environments using HMDs 3D (Yoon, 2022). Symptoms of cybersickness are reported to include discomfort, nausea, vertigo, disorientation, sweating, headache, difficulty in focusing, difficulty in concentrating, and eye fatigue (Preciado et al., 2021). In general, the main symptoms of motion sickness caused using transportation are nausea and gastrointestinal symptoms, and simulator sickness is said to have the most eye movement disorders. In cyber motion sickness, disorientation-related symptoms such as dizziness and vertigo are reported to be the most common (Dennison et al., 2017).

The neural mechanisms of motion sickness are still unclear, but there are three theories that are currently being discussed in many studies. The first theory is the sensory conflict theory, also known as sensory mismatch and neural mismatch. The sensory conflict theory states that in a virtual reality environment, the visual information received by the visual senses and the information received by the vestibular system are in disharmony with each other, causing a conflict between the two senses. In the virtual environment, the user receives a signal to move in a certain direction only by visual stimuli, but since there is no input information of acceleration and linear acceleration from the vestibular nerve, the actual physical movement according to the visual information is inconsistent. This conflict between the senses has been reported to cause motion sickness (Risi & Palmisano, 2019). The second theory is the postural instability theory. This theory is explained from several research perspectives, including ecological psychology, which starts from the premise that one of the basic behavioral goals of animals is to maintain a stable posture, which is crucial for survival, and that failure to do so in certain environments leads to postural instability, which in turn leads to distant symptoms (Palmisano et al., 2017). In addition, other studies have shown that our bodies are always balanced to maintain stability, but in virtual reality, due to the acceleration and rotation of the virtual environment, it is difficult to maintain postural stability, which leads to cyber sickness (Reason, 1978).

The third theory is neural mismatch, where the efferent nerve involved nerve involved in motor neuron mechanisms sends motor signals from the central neural system (CNS) to the peripheral neural system. Currently, when the stored afferent nerve signal is transmitted to the exercise system, it is copied to generate an efferent nerve duplicate. The copied signals are stored as patterns, and when planning future exercise activities, a pattern appropriate for the expected movement is selected. Previous studies have shown that it maintains an efferent nerve pattern copied before the afferent nerve, and when movement begins, motion sickness occurs when the two patterns are different by comparing the generated sensory signal with the selected efferent nerve radiation (Yang et al., 2015). However, another linear study reported a neural mismatch (Han & Kim, 2011). These various theories can be applied to situations in which cyber motion sickness occurs, among which sensory mismatch theory, which explains the mismatch between visual stimulation and sensory feedback, can be seen as the most likely cause of cyber motion sickness (Gavgani et al., 2018). Among the three theories of cyber motion sickness, this theory, which means a mismatch between visual stimulation and acceptance sensory feedback, is the most frequently mentioned theory in cyber motion sickness (Golding & Patel, 2017). The relevance of visual function or visual skills to cybersickness symptoms described in this theory is based on 1): Virtual Reality's Head Mounted Displays (HMDs) utilize three-dimensional based devices that exploit binocular disparity, and 2) the fact that a significant number of participants in a Head Mounted Display Virtual Reality simulation study dropped out due to motion sickness, but did not drop out in the same desktop Virtual Reality, suggests that the configuration and presence of three-dimensional stereoacuity may influence motion sickness symptoms (Guo et al., 2017).

It has also been reported that symptoms such as headaches, eye strain, difficulty focusing, difficulty concentrating, blurred vision, and dizziness are like those seen in problems with vision function (Griffin & Newman, 2004). Furthermore, research on visual fatigue from viewing three-dimensional stereoscopic images has shown that visual fatigue increases when the image exceeds the corresponding depth of focus range, or when there is a change in depth (Yano et al., 2004). The fact that head-mounted displays (HMDs) are three-dimensional devices that utilize binocular disparity, the similarity of cyber sickness symptoms to symptoms of problems with visual functions, and the clinical prevalence of motion sickness symptoms such as disorientation, which is expressed as dizziness when visual functions are impaired, suggest a strong association between the visual system or visual functions and the development of cyber sickness symptoms (Lo & Richard, 2001).

Although cybersickness is caused by experiencing virtual reality, there are many different triggers for cybersickness. The factors that cause cyber sickness are visual fatigue and dizziness caused by too low screen quality, such as display quality and flicker, and hardware characteristics such as screen resolution, response time, and refresh rate, and rapid head movement and latency. The second is content, which is a conflict between the visual and other sensory pathways, and the inconsistency of visual, auditory, vestibular, and motion feedback is believed to cause cyber sickness. The last one is personal characteristics such as age, gender, and previous experience with virtual reality (Kennedy et al., 1993; Rebenitsch et al., 2016).

In previous studies on the above factors that cause cybersickness, researchers have studied how to reduce cybersickness in virtual reality, such as continuity of viewpoint, production using a static coordinate system, and the use of binaural recording. Since cybersickness appears when visual information and signals from the vestibular system conflict with each other, it was said that including fixed visual elements in 3D stereoscopic images can reduce cyber sickness, and if sound can be transmitted by creating a three-dimensional sound like creating a 3D stereoscopic image using two images perceived by the retina due to binocular disparity, cyber sickness can be reduced. Finally, when producing 3D stereoscopic images in virtual reality games, it is necessary to consider the appropriateness of the speed of the image, the setting of the viewing angle considering the convergence phenomenon, and the continuity of the viewpoint to make the player see the 3D stereoscopic image as a single picture (Koo, 2016).

As such, the literature on virtual reality motion sickness is characterized by studies that focus on hardware technology and human physiological differences, and the above hardware factors are complemented by technological advances (Munafo et al., 2017).

In addition, several previous studies have studied the factors that cause cyber sickness in various ways, and have suggested ways to alleviate cyber sickness, such as adjusting the time of experience, adjusting the visual field, using independent vision and foreground, using a virtual body, adjusting the pace of play, alleviating sickness through electrical stimulation, and using peripheral devices (Son & Yoon, 2016).

Even though several previous studies have been conducted, research on the visual components and cyber sickness of virtual reality content is still insufficient. Therefore, this study aims to study cyber motion sickness caused by content characteristics.

2. Method

2.1. Research design

The purpose of this study is to investigate the difference in cyber sickness caused by using contextual content in VR. Therefore, the study was designed and conducted as follows. First, the pretest using a sickness sensitivity questionnaire was conducted. Second, for the main study, three types of content A, B, and C were used once a week for a total of three weeks. Third, the posttest using cyber sickness questionnaire was administered. Fourth, cyber sickness severity, sickness sensitivity, and the relationship between cyber sickness and sickness sensitivity were analyzed.

2.2. Study subjects

In this study, subjects who wish to participate were recruited from the ages of 20 to 40, and 50 people wanted to participate in the study. The sample size was determined using G*Power 3.1.9.4 to determine the number of participants. Side effects that may occur during the study were presented verbally and in writing, and the study was conducted after guiding the subject about the schedule. Users with medical conditions that may affect their ability to safely perform physical activity, anxiety disorders, or post-traumatic stress disorder, as well as pregnant or elderly users and those with a history of photosensitivity seizures, were discouraged from participating, and those who were sick, tired, under the influence of alcohol or drugs, or otherwise not feeling well on the day of participation were advised to participate on a day when they felt better. Also, all clinical, trial protocols and inspection processes were conducted after deliberation and approval by the Research Ethics Committee.

2.3. Virtual reality device and content

The virtual reality device for the study was HTC's VIVE PRO model, HTC's VIVE PRO models are adjustable for individualized pupil distance (PD), and the following are specific specifications for VIVE PRO models. The screen of the HMD is Dual AMOLED 3.5" diagonal, with a refresh rate of 90Hz, resolution of 1440x1600 pixels per eye and 2880 x 1600 pixels combined, field of view of 110°, and sensor that is Steam VR Tracking, G-sensor, Gyroscope, Proximity, and Eye Comfort Setting (IPD). The controller consists of multifunction trackpad, grip buttons, dual-stage trigger, system button, and menu button. The sensor is Steam VR Tracking 2.0 and the room-scale is up to 33' x 33' using four Steam VR Base Station 2.0.

The included two base stations support up to 16'5" x 16'5". The content for measuring cybersickness was selected from commercially available immersive VR content that people are using, representing different characteristics. The content selection was characterized by complete matching of visual stimuli and body movements (A), partial matching of visual stimuli and body movements (B), and mismatching of visual stimuli and body movements (C). All participants measured their level of motion sickness regardless of their experience, and the study procedure consisted of a pretest of motion sickness sensitivity, followed by three types of content (A, B, and C) once a week for a total of three weeks, and a posttest of cyber motion sickness.

2.4. Cyber sickness

Cyber sickness was measured before and after the VR experience using Kennedy's Simulator Sickness Questionnaire (SSQ) (Han & Kim, 2017). The SSQ consists of 16 questions and utilizes a 4-point scale ranging from 0 to 3. Symptoms were divided into three subscales: Nausea, Oculomotor, and Disorientation, which were urther divided into 16 symptoms. Each symptom is assigned an additional point, and the larger the SSQ value, the higher the level of motion sickness. The details of the SSQ are shown in Table 1.

Table 1. SSQ weight calculation

SSQ Symptom	Weight		
	N	O	D
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total	[1]	[2]	[3]
Score	N = [1] x 9.54		
	O = [2] x 7.58		

	D = [3] x 13.92
Total Score	[1] + [2] + [3] x 3.74

2.5. Motion sickness susceptibility questionnaire

The Motion Sickness Susceptibility Questionnaire, developed by Reason and Brand and revised by Golding, has been validated in the literature and has been used to measure susceptibility to motion sickness. The MSSQ consists of a five-point scale that measures the frequency of experiencing motion sickness on nine types of rides: cars, buses, trains, airplanes, small boats, ships, playground swings, playground merry-go-rounds, and roller coasters, categorized as never ridden, ridden but never felt motion sickness, rarely felt motion sickness, sometimes felt motion sickness, and often felt motion sickness, and separated into childhood experiences (MSA) and experiences in the last 10 years (MSB). The calculation for the MSSQ score is MSA = (total sickness score child) x (9) / (9 - number of types not experienced as a child), MSB = (total sickness score adult) x (9) / (9 - number of types not experienced as an adult), and the total score of the MSSQ is calculated as MSA+MSB.

3. Data Analysis

Data statistical analysis was performed using IBM SPSS Statistics 21.00. In this study, descriptive statistical analysis and correlation analysis (Pearson correlation) were performed, and the significance level of all data was $p<0.05$.

4. Results

4.1. General characteristics

Table 2 shows the participants of the study, where out of the total 50 participants, 19 were males and 31 were females. The mean age of the subjects was 24.76±3.69 years (95% CI: 23.81-25.85).

Table 2: General Characteristics of participant's

	Mean±SD	95% CI
Total	50	
Male	19	
Female	31	
Age	24.76±3.69	23.81 ~ 25.85
SD: standard deviation		

4.2. Motion sickness sensitivity

Among motion sickness sensitivity, MSA had a mean of 7.61±6.23 (95% CI 6.09-9.37), MSB had a mean of 6.84±5.50 (95% CI: 5.54-8.51), and MSSQ had a mean of 14.45±10.82 (95% CI: 8.75-12.83) The details are shown in Table 3.

Table 3: Motion sickness sensitivity of participant's

(n=50)	Mean±SD	95% CI
MSA	7.61±6.23	6.09 ~ 9.37
MSB	6.84±5.50	5.54 ~ 8.51
MSSQ	14.45±10.82	8.75 ~ 12.83
SD: standard deviation		

4.3. CyberSickness score

Table 4 shows the cybersickness score for each content. content A had a had a mean of 6.36±9.04 (95% CI: 4.36-9.12) for nausea, 27.44±25.62 (95% CI: 21.00-35.84) for oculomotor discomfort, 47.33±55.04 (95% CI: 33.93-64.96) for disorientation, and 32.61±32.64 (95% CI: 24.94-43.01) for overall cyber sickness. For Content B, the mean nausea score was 32.39±19.26 (95% CI: 27.43-37.63), eye movement discomfort was 67.77±33.14 (95% CI: 59.38-77.70), disorientation was 150.34±87.50 (95% CI: 126.74-174.29), and overall cyber sickness score was 106.22±54.00 (95% CI: 92.73-121.32). For Content C, the mean score for nausea was 29.32±17.97 (95% CI: 24.08-34.60), eye movement discomfort was 60.64±36.56 (95% CI: 49.91-71.06), disorientation was 140.87±83.83 (95% CI: 116.87-163.56), and overall cyber sickness was 97.09±55.01 (95% CI: 80.57-112.51).

Table 4: Cybersickness scores for A, B, and C content

Content	(n=50)	Mean±SD	95% CI	Range
A	SSQ-N	6.36±9.04	4.36 ~ 9.12	0 to 48.62
	SSQ-O	27.44±25.62	21.00 ~ 35.84	0 to 98.54
	SSQ-D	47.33±55.04	33.93 ~ 64.96	0 to 180.96
	SSQ-TS	32.61±32.64	24.94 ~ 43.01	0 to 119.68
B	SSQ-N	32.39±19.26	27.43 ~ 37.63	0 to 78.54
	SSQ-O	67.77±33.14	59.38 ~ 77.70	0 to 144.02
	SSQ-D	150.34±87.50	126.74 ~ 174.29	0 to 320.16
	SSQ-TS	106.22±54.00	92.73 ~ 121.32	3.74 to 235.62
C	SSQ-N	29.32±17.97	24.08 ~ 34.60	0 to 67.32
	SSQ-O	60.64±36.56	49.91 ~ 71.06	0 to 144.02
	SSQ-D	140.87±83.83	116.87 ~ 163.56	0 to 278.40
	SSQ-TS	97.09±55.01	80.57 ~ 112.51	3.74 to 213.18
SD: standard deviation				

4.4. Correlations between cybersickness factors by content

To determine the relative influence of cybersickness factors by content, a Pearson correlation analysis was conducted to examine the correlations. Content A showed the highest positive correlation between disorientation (SSQ-D) and cybersickness (SSQ-TS) with a correlation of r=.946, p=.000.

Table 5. Relationship between content and SSQ (n=50)

Content		SSQ-N	SSQ-O	SSQ-D	SSQ-TS
A	SSQ-N	1			
	SSQ-O	.565***	1		
	p	.001			
	SSQ-D	.702***	.771**	1	
	p	.001	.001		
	SSQ-TS	.814***	.893**	.946***	1
	p	.001	.001	.001	
B	SSQ-N	1			
	SSQ-O	.649***	1		
	p	.001			
	SSQ-D	.754***	.825***	1	
	p	.001	.001		
	SSQ-TS	.881***	.893***	.954***	1
	p	.001	.001	.001	
C	SSQ-N	1			
	SSQ-O	.755***	1		
	p	.001			
	SSQ-D	.814***	.890***	1	
	p	.001	.001		
	SSQ-TS	.907***	.939***	.967***	1
	p	.001	.001	.001	
*p<.05, **p<.01, ***p<.001					

In contrast, nausea (SSQ-N) and oculomotor discomfort (SSQ-O) were positively correlated with a correlation of r=.565, p=.000 (Table 17). Content B had the highest positive correlation between disorientation (SSQ-D) and cyber sickness (SSQ-TS) with a correlation of r=.954, p=.000. Conversely, nausea (SSQ-N) and oculomotor discomfort (SSQ-O) had the lowest positive correlation with r=.649, p=.000 (Table 18). Content C had the highest positive correlation between disorientation (SSQ-D) and cybersickness (SSQ-TS) with a correlation of r=.967, p=.000. Conversely, nausea (SSQ-N) and oculomotor discomfort (SSQ-O) had the lowest positive correlation (r=.755, p=.000) (Table 5).

4.5. Correlation between motion sickness sensitivity and cyber motion sickness factors

Pearson correlation analysis was conducted to analyze the correlation of motion sickness susceptibility factors: motion sickness experience before age 12 (MSA), motion sickness experience in the past 10 years (MSB), motion sickness sensitivity (MSSQ), content-specific nausea (SSQ-N), eye movement discomfort (SSQ-O), disorientation (SSQ-D), and cyber sickness (SSQ-TS). Based on the results, Content A, content A showed the highest positive correlation between motion sickness before age 12 (MSA) and nausea (SSQ-N) with a correlation of r=.326, p=.021, and was also correlated with correlated with motion sickness sensitivity (MSSQ) and nausea (SSQ-N) with a correlation of r=.292, p=.040, while

there was no further correlation between content A and cyber sickness. Content B was correlated with Motion Sickness Assessment (MSA) before age 12. The correlation between motion sickness sensitivity (MSSQ) and nausea (SSQ-N) was r=.450, p=.001, the highest positive correlation among the correlations. In contrast, the correlation between motion sickness sensitivity (MSSQ) and ocular discomfort (SSQ-O) was r=.291, p=.041, which was the lowest positive correlation among the correlations. Content C did not correlate with motion sickness sensitivity and cyber sickness (Table 6**)**.

Table 6. Relationship between MSSQ and SSQ (n=50)

Content		SSQ-N	SSQ-O	SSQ-D	SSQ-TS
A	MSA	.326*	.236	.189	.267
	MSB	.205	.110	.108	.149
	MSSQ	.292*	.192	.164	.229
B	MSA	.404**	.272	.450**	.422**
	MSB	.363**	.264	.376**	.373**
	MSSQ	.417**	.291*	.450**	.433**
C	MSA	.090	.116	.158	.132
	MSB	.048	.049	.084	.066
	MSSQ	.076	.092	.134	.110
*p<.05, **p<.01, ***p<.001					

5. Discussion

Virtual reality is a technology that creates artificial environments and situations that resemble reality. These artificial virtual environments and situations stimulate the user's senses to experience the same space and time as if they were real, thus crossing the boundary between reality and imagination (Moon et al., 2020). Recently, the interest in the content industry using virtual reality has been increasing, and virtual reality is changing most areas of life such as education, travel, exercise, and play by fusing the online virtual world with the offline real world.

However, the biggest problem with these virtual reality devices, in addition to weight and price, is cybersickness (Yoon, 2022). Cybersickness has been a common problem in other media such as PC games and movies, but it has become a major problem in virtual reality because the characteristics of virtual reality wearing a head-mounted display make it difficult for the subject to recognize his or her condition, and it can cause not only sickness but also safety problems. However, there has not yet been a breakthrough method for solving motion sickness in the use of virtual reality content, and many related studies aim to alleviate motion sickness.

This study aimed to investigate cybersickness as it relates to the use of various virtual reality content. To do this, a survey was conducted to find out cybersickness and sickness susceptibility. In terms of cybersickness score by Content B had the highest cyber sickness score, followed by Content C, then Content A. In addition, among the factors of cybersickness, the disorientation factor was the highest for all three contents, which suggests that the virtual reality contents in this study are the most likely to cause cybersickness due to disorientation. It is believed that cybersickness was induced faster in Content C than in Content B because the situation of sensory inconsistency appears irregularly between the situation of sensory consistency and the situation of sensory inconsistency in Content B, while the situation of sensory inconsistency appears from the beginning to the end in Content C, and linear motion and rotational motion (pitch, yaw, and roll axis rotation) appeared at the same time, which made the subject exposed to more sensory inconsistency. Previous studies have shown that cybersickness can be triggered by forced scene motion, and that linear motion and simultaneous scene rotation have been reported to cause severe cybersickness in VR (Guo et al., 2017).

The research hypothesis for the relationship between motion sickness sensitivity and cyber sickness was that higher motion sickness sensitivity scores would be associated with higher cybersickness scores. However, contrary to the research hypothesis, the results showed that the correlation between motion sickness sensitivity and cyber sickness factors differed depending on the content. Content B correlated with all cybersickness factors, Content A correlated with nausea factors, but Content C did not correlate with all cybersickness factors. Through simple regression analysis, it was found that motion sickness sensitivity had a significant effect on the cybersickness score of Content B. The reason why motion sickness sensitivity only affected all cybersickness factors in Content B is that the motion sickness sensitivity questionnaire quantifies the frequency of motion sickness on a vehicle, and it was thought that using virtual reality in Content B provides a similar sensation to using a vehicle in reality. Content B was able to move around in VR using three different methods. The first method was to move to the sensory matching state by actually walking in the room scale and moving in virtual reality. The second method was to use the movement keys on the controller to move around in VR, but not actually move the subject's body. The third method was to drive a car in the virtual world to move around, but not actually move the subject's body. The second and third of these three methods are similar to the principle of using a vehicle in real life, where the vehicle moves while the body does not, and this result has been reported in previous studies to be particularly uncomfortable and exacerbate motion sickness. Content C was based on a real roller coaster and was predicted to be correlated with motion sickness sensitivity. However, there was no correlation between motion sickness sensitivity and cybersickness. Of the 50 subjects in this study, 21 experienced motion sickness on a roller coaster in real life, but more subjects experienced motion sickness on a virtual reality roller coaster than on a real roller coaster. This is because the roller coaster in virtual reality expresses the sense of speed and rotation through rapid changes in the background and the tilt of the screen, and the visual information conveys fast speed and rotation, but the vestibular sensation or somatosensory sensation does not convey fast speed and rotation, which is different from the real roller coaster where the visual information and the vestibular sensation or somatosensory sensation are consistent due to the mismatch of senses. Previous studies have shown that the rolling motion of the scene is a factor in causing cybersickness. As such, it is inferred that there is no correlation between susceptibility and cybersickness because the susceptibility questionnaire, which is the frequency of sickness on actual rides, and the susceptibility factor for Content C are applied differently. In addition, since cybersickness was measured subjectively using the SSQ, future research should be conducted on contextual content and cybersickness with objective indicators of cybersickness.

6. Conclusion

Content A induced the least cybersickness, and the factors that reduced cybersickness were that sensory coherence was maintained when using VR and a stereoscopic coordinate system was utilized. Content

B induced the highest cybersickness score and the most diverse distribution of usage time. The correlation between cybersickness and sickness sensitivity suggests that the cybersickness factors of Content B are similar to those of real-life sickness, while Content C induced cybersickness quickly and showed strong cybersickness. As mentioned above, this study only used one VR device only one VR device to avoid the influence of hardware characteristics, and conducted a study on contents with different characteristics, and found that the main sense that causes cyber sickness is the visual factor. In conclusion, this study provides initial evidence that VR designs inducing sustained visual-vestibular discordance may exacerbate cybersickness, particularly disorientation symptoms. The findings highlight the relevance of sensory conflict theories to VR sickness etiology. Further research with larger samples, objective sickness measures, and expanded content designs is critical to elucidate VR cybersickness mechanisms.

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References

Bric, J. D., Lumbard, D. C., Frelich, M. & Gould, J. C. (2016). Current state of virtual reality simulation in robotic surgery training: A review. *Surg. Endosc*, 30, 2169-2178.

Chang ,E., Hwang, I., Jeon, H., Chun, Y., Kim, H. T. & Park, C. (2013). Effects of rest frames on cybersickness and oscillatory brain activity. *International Winter Workshop on Brain-Computer Interface*, 62-64. DOI:10.1109/IWW-BCI.2013.6506631.

Davis, S., Nesbitt, K. & Nalivaiko E. (2014). A systematic review of cybersickness. *Proceedings of the 2014 Conference on Interactive Entertainment*, 12, 1-9.

Dennison, M. S. & D'Zmura M. (2017). Cybersickness without the wobble: Experimental results 53speak against postural instability theory. *Appl. Ergon*, 58, 215-223.

Gavgani, A. M., Walker, F. R., Hodgson, D. M. & Nalivaiko, E. (2018). A comparative study of cybersickness during exposure to virtual reality and "classic" motion sickness: are they different?. *J Appl Physiol*, 125(6), 1670-1680.

Golding, J. F. & Patel, M. (2017). Meniere's, migraine, and motion sickness. *Acta Otolaryngol*. 137(2), 495-502.

Guo, C. C., Chen, D. J., Wei, I. Y., So, R. H. & Cheung, R. T. (2017). Correlations between individual susceptibility to visually induced motion sickness and decaying time constant of after-nystagmus. *Appl. Ergon*, 63, 1-8.

Griffin, M. J. & Newman, M. M. (2004). Visual field effects on motion sickness in cars. *Aviat Space Environ Med*, 75(9), 739-748.

Han, K. H. & Kim, H. T. (2011). The cause and solution of cybersickness in 3D virtual environments. *Korean Journal of Cognitive and Biological Psychology*, 23(2), 287-299.

Jung, J. Y., Cho, K. S. & Choi, J. H. (2017). Causes of cyber sickness of VR contents: An experimental Study on the view point and movement. *The Journal of the Korea Contents Association*, 17(4), 201-206.

Kennedy, R. S., Lane, N. E., Berbaum, K. S. & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, 3(3), 203-220. DOI:10.1207/s15327108ijap03033.

Keshavarz, B., Hecht, H, & Lawson, B. D. (2014). Visually induced motion sickness: Causes, characteristics, and countermeasures. In *Handbook of Virtual Environments: Design, Implementation, and Applications*, eds KS. Hale and KM. Stanney(Boca Raton, FL: CRC Press), 652–703.

Koo, J. Y. & Kim, S. I. (2019). A study on the cyber motion sickness of VR content–focused on content environment. *Journal of the Korea Convergence Society*, 10(3), 135-140.

Keith, N., Davis, S., Blackmore, K. & Nalivaiko, E. (2017). Correlating reaction time and nausea measures with traditional measures of cybersickness. *Displays*, 48, 1-8.

Lo, W. T. & So, R. H. (2001). Cybersickness in the presence of scene rotational movements along different axes. *Applied ergonomic*, 32(1), 1-14.

Moon, B., Nam, S., Kim, D., Kim, H. J., Park, E. J. & Lim, H. K. (2020). Design and production of educational VR contents learning about design's principle and flow. *Asia-pacific Journal of Convergent Research*, 6, 31-39.

Munafo, J., Diedrick, M. & Stoffregen, T. A. (2017). The virtual reality head-mounted display Oclus Rift induces motion sickness and is sexist in its effects. *Exp. Brain Res*, 235, 889-901.

Palmisano, S., Mursic, R. & Kim, J. (2017). Vection and cybersickness generated by head-and-display motion in the Oculus Rift. *Displays*, 46, 1-8.

Preciado, C., Starrett, M. J. & Ekstrom, A. D. (2021). Assessment of a short, focused training to reduce symptoms of cybersickness. *Virtual and Augmented Reality*, 27(4), 361–377.

Rebenitsch, L. & Owen, C. B. (2016). Review on cybersickness in applications and visual displays. *Virtual Reality*, 2(2), 101-125.

Reason, J. T. (1978). Motion sickness adaptation: A neural mismatch model. *J R Soc Med*, 71(11), 819-829.

Risi, D. & Palmisano, S. (2019). Effects of postural stability, active control, exposure duration and repeated exposures on HMD induced cybersickness. *Displays*, 60, 9-17.

Son, J. W. & Yoon, H. S. (2016). A study on cyber sickness mitigation analysis and its' applications. *The Korean Journal of Animation*, 12(4), 59-68.

Yang, H., Park, H., Kim, J. & Park J. (2015). Survey on cyber motion sickness. *Korean Institute of Information Scientists and Engineers*, 6, 1401-1403.

Yano, S., Emoto, M. & Mitsuhashi, T. (2004). Two factors in visual fatigue caused by stereoscopic HDTV images. *Displays*, 25(4), 141-150.

Yoon, O. H. (2022). Exploration of question generation strategies in the Havruta class model. *Asia-pacific Journal of Convergent Research Interchange*, FuCoS, 8(6), 165-176. DOI:http://dx.doi.org/10.47116/apjcri.2022.06.15.