International Journal of Advanced Culture Technology Vol.12 No.2 345-352 (2024)
DOI https://doi.org/10.17703/IJACT.2024.12.2.345

IJACT 24-6-38

Development of an evaluation tool model for the effective measurement of cyber motion sickness in immersive virtual reality

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Abstract

We are designed to solve cyber motion sickness, an important task that must be addressed for the growth of the virtual reality content industry. Not only the industry but also academia are paying a lot of attention. However, despite long interest and research on the phenomenon of cyber motion sickness, a solution has not been drawn. This is deeply related to the lack of tools that can effectively measure cyber motion sickness. Therefore, in this paper, prior studies on cyber motion sickness were analyzed to develop a tool that can effectively measure cyber motion sickness when users experience immersive virtual reality. The measurement method of cyber motion sickness used in previous studies, each characteristic and limitation, and common factors related to cyber motion sickness were analyzed. Each of the related factors was derived as sub-factors. Based on the analyzed contents, an effective cyber motion sickness measurement evaluation tool model in immersive virtual reality was presented. It is expected that the evaluation tool model can be used for the study of cyber motion sickness.

Keywords: *Cyber Motion Sickness, Virtual Reality, Virtual Reality Content*

1. INTRODUCTION

Recently, as various virtual reality devices including head mounted displays (HMDs) have been released in the market and are widely distributed, virtual reality contents available through them are rapidly emerging. According to a survey by Allied market research, the global virtual reality market was valued at $33 billion in 2021, and it is expected to reach $446.6 billion by 2031, continuing its growth at an average annual growth rate of 30.1% from 2022 to 2031. [1].

Expectations are rising as the virtual reality market size increases, but problems with virtual reality technology itself are pointed out as obstacles to market growth [2]. When experiencing virtual reality using HMD, some users were able to experience cyber motion sickness, as this experience brings inconvenience to users and leads to negative perceptions of virtual reality experiences [3].

Cyber motion sickness is an important task that must be solved in terms of the growth of the virtual reality content industry, and the industry as well as academia are paying a lot of attention. However, despite long-term interest and research on cyber motion sickness, users are still experiencing it [2]. This is deeply related to the lack of tools that can effectively measure cyber motion sickness [4].

Manuscript received: March 15, 2024 / revised: April 20, 2024 / accepted: May 5, 2024
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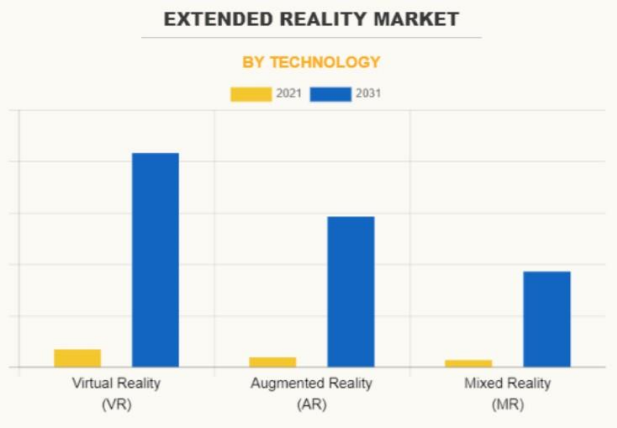

Figure 1. Graphs for forecasting VR/AR/MR global virtual reality market size for 2021 and 2031 based on annual average growth rate

In this paper, prior research on cyber motion sickness is analyzed in different directions to develop a tool that can effectively measure cyber motion sickness when users experience immersive virtual reality. First, the measurement method of cyber motion sickness used in previous studies, and each characteristic and limitation are analyzed. After that, the factors related to cyber motion sickness are analyzed and each sub-component is derived. Based on the final analysis, an effective cyber motion sickness measurement evaluation tool model in immersive virtual reality is presented, and future research directions are proposed.

2. Theoretical background

2.1 Immersive Virtual Reality

Virtual reality is classified into various criteria according to previous studies. Depending on the system in which virtual reality is implemented, Kim Woo-sang (2018) classified it into window type, mirror type, boarding type, cave type, and immersive type in previous studies [5], and Kim Young-mi (2016) classified it into immersive, semi-immersion type, and desktop type in previous studies [6], and the Korea Information and Communication Technology Association (2017) classified virtual reality into immersive virtual reality and non-immersion virtual reality [7]. The various types of virtual reality classification systems shown in previous studies commonly cause cyber motion sickness, but in this paper, a cyber motion sickness measurement evaluation tool model was developed by limiting the scope to the immersive virtual reality [8], where the cyber motion sickness phenomenon can occur most frequently. Immersive virtual reality aims to provide a more realistic experience by utilizing the user's senses such as sight and hearing in a virtual environment, and recently, HMD has been used to provide a higher immersion and presence virtual reality experience [9]. Based on the above, immersive virtual reality defined in this paper refers to virtual reality using HMD equipment.

2.2 Cyber Motion Sickness

In the past, motion sickness symptoms, which were limited to special situations in the past, have been expanded to various situations due to the recent development of technology and cultural contents, and their severity is also gradually increasing [10]. In previous studies, motion sickness symptoms occurring in various situations were classified into sub-types according to the situation in which visual information was implemented. It can be classified into simulator sickness [11], 3D sickness(3D Sickness) [12] for video games, and Cyber Sickness [13] for virtual reality. Cyber sickness occurs through display devices such as screens, monitors, and smartphones including HMD [4], but cyber sickness defined in this paper refers to motion sickness symptoms in virtual reality using HMD equipment.

2.2.1 Method of Measuring Cyber Motion Sickness

In previous studies, subjective and objective measurement methods were used to measure cyber sickness that occurs to users while experiencing virtual reality. The subjective measurement method relies on the user's subjective data, and the representative measurement method among many methods is SSQ (Simulation Sickness Questionnaire). SSQ is a method developed by Kennedy (1993), and scores a total of 16 items according to the degree of motion sickness are set and reflected on a 4-point scale (0=none, 1=slight, 2=normal, 3=severe). It is then divided into three subscales (Nausea, Eye movement, Disorientation) along with the sum of the scores, and the higher the sum of the scores, the more serious cyber sickness was experienced [14]. In the case of SSQ, there is an advantage that anyone can easily describe their current state, but there is a limitation that they have no choice but to rely only on the user's subjective data due to the nature of the questionnaire. In order to solve this problem, a tool capable of objectively measuring the degree of cyber sickness was required [4]. Most objective measurement methods can record physical reactions in real time as the user experiences virtual reality, and through this, an index that reflects cyber motion sickness is derived. Since electrophysiological signals such as electroencephalogram (EEG), gastric conduction (EGG), and electrocardiogram (ECG) are used as the main tools of the objective measurement method, it has the advantage of being able to measure the symptoms of cyber motion sickness quantitatively. However, there is a limitation in that it is difficult to apply it in the actual virtual reality industry site due to the user's inconvenience of wearing a sensor, long-term measurement and analysis time, and difficulty in applying the field in real time [15].

In this paper, a subjective measurement method was adopted to develop a cyber motion sickness measurement evaluation tool model. The reason is that it is a more intuitive and accessible method in terms of application. However, in order to overcome this, the limitation of having to rely on the subjective judgment of the user was clearly shown, the common cyber motion sickness factors appearing in previous studies were analyzed, sub-components were derived, and this was applied to the questionnaire item. Through this, it will be possible to measure more accurate and diverse cyber motion sickness factors.

2.2.2 Factors Related to Cyber Motion Sickness

Among the various theories explaining the factors of cyber motion sickness, Sensory Conflict Theory and Postural Instability are typically verified and supported through prior research. Sensory conflict theory is an information mismatch between our body's vestibular organs, which feel acceleration due to sight and movement seen while moving in a virtual environment. If the user is moving in a virtual environment and the user's body is fixed in reality, this increases the conflict between the visual and vestibular organs, resulting in cyber motion sickness [16]. Postural instability theory tries to balance our body while watching a video rotating visually in a virtual environment to maintain posture stability, but in an unfamiliar environment such as a virtual environment, the existing posture control strategy cannot take off its ability, resulting in increased posture instability and as a result, cyber motion sickness [17].

However, these theories do not completely identify the factors of cyber sickness. Therefore, in this paper, the common factors of cyber sickness that appear in previous studies were analyzed and each sub-component was derived as shown in Table 1

Table 1 Cyber motion sickness factors and sub-components through prior research

Main Cause	Subcomponents	Details	Reference
Content	Independent Visual Foreground	Cyber motion sickness can be reduced by using an independent visual foreground that helps stable eye	Moon Sung Chul (2018) [15] Hwang Injae (2012) [18] Song Eun Ji (2017) [19]

		movement.	Son Junwoo (2016) [25]
	Point of View	Cyber motion sickness can be reduced by using a third-person perspective rather than a first-person perspective.	Moon Sung Chul (2018) [15] Jung Ji-young (2017) [20]
	Pitch-Yaw	Cyber motion sickness may be reduced by using a vertical axis rotation movement rather than a horizontal axis rotation movement.	Jung Ji-young (2017) [20] Qiao Rongrong (2018) [24]
	Rest Frames	By applying the stationary coordinate system, the user feels more stable and can reduce cyber motion sickness.	Han Kyung-hoon (2011) [17] Qiao Rongrong (2018) [24]
	Out-focusing	By adjusting the clarity according to the user's viewpoint, cyber motion sickness may be reduced.	Park Jaehyun (2017) [22]
	Speed	By adjusting the moving speed of the screen or character, cyber motion sickness can be reduced.	Qiao Rongrong (2018) [24] Kim Young Yoon (2002) [26]
Hardware	Field of View	By adjusting the viewing angle, cyber motion sickness can be reduced.	Moon Sung Chul (2018) [15] Han Kyung-hoon (2011) [17] Jung Geunsoo (2018) [21] Park Jaehyun (2017) [22] Jang Hyung Jun (2018) [23] Qiao Rongrong (2018) [24] Son Junwoo (2016) [25] Kim Young Yoon (2002) [26]
	Motion Platform	It can reduce cyber motion sickness by minimizing collisions between vision and vestibular organs by giving physical movement.	Moon Sung Chul (2018) [15] Han Kyung-hoon (2011) [17] Park Jaehyun (2017) [22] Son Junwoo (2016) [25]
	Delay time	Cybersickness can be reduced by reducing the delay between movement and visual information.	Park Jaehyun (2017) [22] Jang Hyung Jun (2018) [23] Qiao Rongrong (2018) [24]
	Display Resolution	Cybersickness can be reduced by adjusting the resolution of stereoscopic recognition using HMD.	Moon Sung Chul (2018) [15] Jang Hyung Jun (2018) [23]
	Weight	Cybersickness can be reduced by controlling the physical burden with the weight of the HMD.	Qiao Rongrong (2018) [24]
	Flicker	Cybersickness can be reduced depending on the frequency of display blinking.	Qiao Rongrong (2018) [24]
User Characteristic	Motion Sickness	The poorer your health or the more frequently you experience motion	Qiao Rongrong (2018) [24]

s	Sensitivity	sickness in your daily life, the more susceptible you are to cybersickness.	
	Age or Gender	The older the age, the more sensitive women are to cyber sickness than men.	Moon Sung Chul (2018) [15] Qiao Rongrong (2018) [24]
	Binocular Parallax	The more severe the difference between binocular distance and viewing angle, the more sensitive it is to cyber motion sickness.	Moon Sung Chul (2018) [15]
	VR Experience	The less familiar you are with virtual reality, the more sensitive you are to cyber motion sickness.	Moon Sung Chul (2018) [15] Qiao Rongrong (2018) [24]

3. Cyber Motion Sickness Measurement Evaluation Tool Model

The cyber motion sickness measurement evaluation tool model developed in this paper is divided into before and after experiencing virtual reality and is measured twice. The reason for measuring before experiencing virtual reality is not to make a measurement error due to deviations between users, which is the limitation of SSQ. As shown in Table 2, cybersickness measurement values for user characteristics were measured, and a score of 3 or less was considered appropriate, a score of 4 or more and 6 or less was average, and a score of 7 or more and 9 or less was considered vulnerable, and the evaluation was divided into a control group. Proceed. The measurement after experiencing virtual reality is as shown in Table 3. Based on the contents of Table 1, the cybersickness level for content and hardware is measured based on a total of 12 items. If the score is 20 or higher, the user experiences cybersickness. It is judged that it was done.

Table 2. Measurement of cyber motion sickness for user characteristics

Number	Category	Score
1	Do you have any health problems recently? (Good = 0, Normal = 1, Bad = 2)	
2	Do you often experience symptoms of motion sickness in your daily life? (Not included = 0, Sometimes = 1, Often = 2)	
3	How old is the author? (30 years old or older = 0, 30-50 years old = 1, 51 years of age or older = 2)	
4	What is the gender of the author? (Male = 0, Female = 1)	
5	How many times have you experienced virtual reality? (More than 6 times = 0, 3-5 times = 1, No more than 2 = 2)	

Table 3. Measurement of cyber motion sickness for content and hardware
(0 = not at all, 1 = sometimes, 2 = often, 3 = always)

Number	Category	Score
1	Did you feel secure with repeated or directionally predictable targets?	
2	Did you feel awkward or uncomfortable about the timing?	

3	Did you feel awkward or uncomfortable when moving your head?
4	Did you feel secure through the background of no movement?
5	Did you feel awkward or uncomfortable due to the clarity of the background outside the viewpoint?
6	Did you feel awkward or uncomfortable with the moving speed of your screen or character?
7	Did you feel awkward or uncomfortable with your viewing angle?
8	Did you feel awkward or uncomfortable when you gave physical movement?
9	Did you feel awkward or uncomfortable due to the delay time between movement and visual information?
10	Did you feel awkward or uncomfortable with the HMD resolution?
11	Did you feel any physical strain from the weight of the HMD?
12	Did the display blink get in the way?

4. Conclusion

Cyber motion sickness is an important task that must be solved in terms of the growth of the virtual reality content industry, and the industry as well as academia are paying a lot of attention. However, despite long-term interest and research on cyber motion sickness, users are still experiencing it. This is deeply related to the lack of tools that can effectively measure cyber motion sickness.

Therefore, in this paper, prior studies on cyber motion sickness were analyzed in different directions to develop a tool that can effectively measure cyber motion sickness when users experience immersive virtual reality. Through the analyzed prior studies, the existing method of measuring cyber motion sickness was investigated, and the characteristics and limitations of each were investigated. After that, the factors related to cyber motion sickness were analyzed and each sub-component was derived. Based on the final analysis, a cyber motion sickness measurement evaluation tool model was developed in immersive virtual reality.

In the future, it is expected that experimental verification using the evaluation tool model will present a new perspective on finding solutions to cyber sickness in virtual reality.

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