Title	Reduce VR sickness symptoms by adaptive training system
Sub Title	
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Publisher	慶應義塾大学大学院システムデザイン・マネジメント研究科
Publication year	2022
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2022年度システムエンジニアリング学 第344号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40002001-00002022-0002

Master's Dissertation 2022

Reduce VR Sickness Symptoms by Adaptive Training System

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September 2022

Graduate School of System Design and Management,

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Major in System Design and Management

SUMMARY OF MASTER'S DISSERTATION

Student Identification Number	82034531	Name	JIANG CHUHAN

Title

Reduce VR Sickness Symptoms by Adaptive Training System

Abstract

When using VR, some people may experience VR sickness symptoms, which can seriously affect the user experience. Existing solutions to VR sickness are mainly based on improving software or hardware to make users less prone to VR sickness symptoms, but there are individual differences in VR sickness.

This research creates a new solution to reduce VR sickness. The research focuses on a system for VR adaptive training. This system allows users to gradually adapt to the walking interaction of VR flexibly changing the navigation speed while observing the user's condition, so that they can adapt to the VR environment in a short time. And the system reduce the pain in the process of adapting to VR sickness symptoms. Tolerance to VR sickness symptoms is builed to make sure users can adapt to the VR environment at various navigation speeds.

This system was evaluated through experiment and questionnaire. The results were obtained that this system can help users reduce VR sickness symptoms. Besides, after experiencing the adaptive training system, users' interest in VR increased.This system can reduce the user's fear of VR due to VR sickness symptoms. It may expand the VR market and promote the development of VR in the future.

Key Word(5 words)

VR Sickness, Adaptation, Adaptive Training, Navigation Speed,
Walking Interaction

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1 INTRODUCTION

1.1 VR Sickness

Virtual reality technology refers to the use of virtual reality headsets or multi-projection settings to generate visuals, sounds, and other sensations that give the user the feeling of being in a virtual environment. This gives the user the impression that they are actually present in the virtual environment. A user of virtual reality equipment is given the ability to freely walk around and perform a variety of actions on virtual objects when using the device. Virtual reality technology is able to accurately simulate a number of perceptual tasks, such as vision, hearing, and touch in the natural environment thanks to the support of a variety of technologies. This technology not only enables users to have an authentic reality experience by means of a virtual reality system, but it also enables users to transcend objective limits such as time and place in order to have an experience that is not feasible in the actual world. Users are able to see and imagine what the virtual world is like thanks to a characteristic of technology known as virtual reality that completely submerges human senses in the environment of the virtual world.

In recent years, virtual reality technology has become increasingly popular and is now being utilized more regularly in people's day-to-day lives. Virtual reality technology is one of the most cutting-edge computer simulation technologies that are now available. The use of virtual reality technology is currently widespread across a variety of sectors, including the educational sector, the entertainment industry, and the social networking sector. In addition to this, as the metaverse continues to grow, an increasing number of people will employ virtual reality technology. One may make the argument that the technology behind virtual reality is advancing at a rapid rate, becoming more pervasive and profound as it does so, and incorporating itself into every element of people's lives.

However, a major issue with virtual reality technology is that users may occasionally experience VR sickness, which is analogous to the traditional indicators of motion sickness. This is a problem because users should not feel nauseous when using the technology. Virtual reality sickness can present itself in a number of different ways, and the following is a list of some of the symptoms that could occur:

- Eye strain
- Headache
- Pallor
- Sweating
- Dryness of mouth
- Fullness of stomach
- Disorientation
- Vertigo
- Ataxia
- Nausea
- Vomiting.

VR sickness symptoms not only cause consumers discomfort, but they also negatively affect their experience. Many people may have VR sickness symptoms, especially while using virtual reality for the first time. Users are unable to fully immerse themselves in the virtual environment because of this, which negatively impacts their user experience. Immersion is one of the main benefits of virtual environments, though.

Therefore, VR sickness may prevent users from enjoying the benefits of the technology. More significantly, VR sickness may cause users to experience severe physical discomfort. Users' interest in virtual reality will be significantly diminished, and they may even become afraid of it, if, despite repeated attempts, they are still unable to adjust to the VR environment and continue to experience VR sickness symptoms.

It is estimated that by 2024, the global market for VR would have increased to more than $12 billion, up from less than $5 billion in 2021[2]. Overall, the industry is making rapid strides toward expansion. It is crucial to address the issue of VR sickness and facilitate a quick and comfortable adaptation to the VR environment since this implies that more and more people will use VR and more and more new users will begin to use it.

1.2 Causes of VR Sickness

1.2.1 Vestibular and VR Sickness

Both VR sickness and motion sickness share some of the same causes and symptoms. There is a strong connection between the vestibular system, the visual impression of one's own motion, and the onset of motion sickness[1]. Figure 1 illustrates the vestibular system, which is responsible for providing information regarding how the head moves and how it is orientated in space. It is made up of the parts of the inner ear that are not responsible for acoustic reception.

Figure 1.1 Diagram of the inner ear

The sensory conflict theory is the hypothesis that has been around the longest and is the one that is known and accepted by the most people. The hypothesis is built on the assumption that there are perceptual conflicts that the body is unable to resolve because of disparities between the multiple senses that offer information about body position and movement. This theory forms the basis for the hypothesis. Simply put, although your body remains static, your mind continues to convince you that you are moving. Your body, inner ears, and eyes are all simultaneously sending your brain signals that are at odds with one another. Your brain's state of confusion and disorientation is directly responsible for your experience of virtual reality illness. The feeling of vestibular motion and the sense of vision are the two primary senses that are involved in motion sickness and motion sickness.

1.2.2 Hardware

The quality of VR largely depends on the hardware. Users should feel less discomfort as virtual reality technology develops. The performance of hardware has improved, yet VR sickness still persists[24][25][26].

There are some display types and modes that can make viewers feel ill when using VR. Users report higher SSQ scores when wearing HMDs, according to experimental findings[4]. This might be related to 3D visualization, which enables the feeling of depth in virtual things. As a result, there may be a discrepancy between what is expected and what is considered to be information. This causes a higher degree of sensory conflict, which causes VR sickness symptoms.

The length of the observable line of sight is known as the field of view (FOV). A display device's maximum viewing angle is known as its hardware FOV. Researchers have suggested a number of ways to modify the hardware FOV in order to reduce VR sickness[5]. The discomfort of the user can be reduced by reducing the hardware FOV.

When a user moves in VR, the hardware device must compute, render, and transmit the image that corresponds to that motion. But this procedure takes time. Because of this, there is a delay between what the user anticipates seeing and what they actually see. Users of VR commonly experience VR sickness because of this. VR sickness can be lessened by reducing the time lag or at least maintaining a consistent time lag size[20][21].

VR sickness is also brought on by the display flickering. [22]Users who experience flicker may experience visual disruptions and suffer eye health consequences. Additionally, flicker perception varies from person to person, making it crucial to take into account individual sensitivities while deploying VR systems[23].

1.2.3 Content

The main cause of VR nausea is VR content. The material has become more intricate and complicated as developers work to increase VR realism, but this does not always translate to a better user experience.

Humans may experience visual stimulation from the light flow in VR content, which may result in VR sickness symptoms. When compared to static visual information, moving visual content makes people feel sicker. In VR situations, the stimulation of movement results in optical flow. The user's dizziness is influenced by their movement's speed, rotation, and oscillation amplitude when in a VR environment.

According to certain studies, viewers' VR motion sickness gets worse as movement speed rises. The results showed that when the speed climbed from 3 m/s to 10 m/s, the degree of nausea and vomiting also increased. If the speed was higher than 10 m/s, the link between speed and VR discomfort vanished. At 10 m/s, users complained of the most discomfort.

Compared to translational motion, users were more uncomfortable while experiencing rotating motion in virtual reality settings. More than two axes were used in the rotational motion, which increased the participants' VR nausea. Users are likely to experience discomfort at oscillation amplitudes of about 0.2-0.3 Hz, according to the experiment.

Motion approaching these frequencies would be difficult for people to control, which would cause motion sickness.

Additionally, in order to improve user immersion, VR scene creators are always working to create increasingly intricate and high-quality VR scenes. However, a decline in VR nausea is not always associated with advancements in VR visual quality. On the other hand, when exposed to crisper and more lifelike visuals, individuals frequently show higher levels of pain. This is due to the sensory distinctions between vestibular and visual information. In other words, when users become increasingly immersed in VR and anticipate vestibular input in line with the visual stimuli, there is confusion between the visual stimuli and the vestibular system.

The content FOV can be changed in addition to the hardware FOV by adjusting the virtual camera's visual effects[27]. Narrowing the content FOV, like with the hardware FOV, is an efficient way to reduce the subjective and objective symptoms of VR disorders. Users won't be able to experience VR's immersion, though, if the FOV is too small. While exploring VR, if the FOV is too small and constrained by it, more head movement is necessary, which could result in VR sickness.

The user's VR sickness symptoms might also be influenced by how long they use VR for. According to several studies, there is a significant correlation between exposure time and SSQ scores. The severity of the VR sickness symptoms increases the longer the user uses VR. In addition, VR equipment has a specific weight, thus wearing it for an extended period of time may result in increasing discomfort for the user. In particular, wearing heavy objects on the head for an extended period of time while using an HMD to enjoy VR will make the user uncomfortable, regardless of the VR content[28].

Two different forms of VR can be categorized as active or passive experiences, depending on their intended use and content. User engagement during VR experiences, such as VR tours, is limited by passive navigation. Passive users can experience severe VR sickness, according to studies. The user experience deteriorates if users are rendered powerless in VR and are made to watch scenes passively.

VR sickness is also brought on by the display flickering. Users who experience flicker may experience visual disruptions and suffer eye health consequences. Additionally, flicker perception varies from person to person, making it crucial to take into account individual sensitivities while deploying VR systems.

1.2.4 Human Factors

While everyone uses the same VR equipment and experiences the same VR content, not everyone experiences VR sickness to the same degree. VR sickness symptoms differ from person to person.

There are numerous research on the subject of how much VR sickness is affected by the user's age[14]. These studies' experiments, however, produced varied outcomes. According to several research, older persons experience more severe VR sickness symptoms than younger people. Studies that show the reverse outcome do exist, though. Compared to the older age group, people with an average age under 35 reported higher total SSQ scores. Nevertheless, based on the findings of the current study, it is impossible to determine with certainty what impact age has on the symptoms of VR sickness. However, the majority of scientists think that age can affect VR diseases.

Similar research on gender variations in VR diseases has produced erratic findings[15]. According to several research[16][17], women score higher on the SSQ than males and are more likely to experience VR problems. Others, who maintain that there are no conclusive gender differences in VR problems, have employed surveys to ascertain this. Whether there is a direct correlation between gender and the level of discomfort is still up for debate.

Additionally, it is well-known that repetitive exposure to the same VR content can lessen the intensity of VR sickness. According to one study, participants who had never used virtual reality before experienced more discomfort, had higher SSQ ratings, and performed worse on VR tasks.

The degree of VR sickness is significantly predicted by one's vulnerability to motion sickness. According to certain research[18][19], persons who are prone to motion sickness are likely to report feeling more uncomfortable in VR.

1.3 VR Sickness Measurements

VR sickness symptoms can be measured in a variety of methods. The degree of discomfort experienced by the user can be measured subjectively or objectively. The most popular measurement technique right now is subjective measurement. In order to identify the symptoms of VR sickness and the severity of the user's symptoms, users fill out questionnaires based on their personal experiences and feelings, which are then reviewed and analyzed. Monitoring the user's physiological status is objective measurement. Since the human body undergoes some changes when VR sickness strikes, it is also possible to evaluate and determine whether the user has VR sickness symptoms and the intensity of the sickness symptoms by observing the changes in these physiological indicators.

1.3.1 Subjective Measurements

Subjective measurement is the user's evaluation of his or her own feelings after participating in a VR experience and completing a questionnaire. The responses to the questionnaire can be used to make an evaluation of both the severity of the user's sickness caused by virtual reality and the symptoms of it. The questionnaire method makes it simple to describe one's present condition. However, due to the fact that the data was collected after the user had completed their VR experience, this does not show VR sickness in real time. The user's evaluation of their own state is likewise greatly vulnerable to personal interpretation. Even for the same symptoms, the measures taken by different users, each with their own unique level of sensitivity and tolerance, can produce quite different findings. This can cause the results to vary widely.

Despite the fact that there are many various kinds of questionnaires accessible, the SSQ[6] is one of the subjective measures that is utilized the most frequently. In addition, in contrast to the comprehensiveness and precision of the SSQ questions, various researchers have developed questionnaires that are extremely succinct and take very little time to report[3].

During the duration of the Fast Movement sickness Scale (FMS)[7], participants are obligated to verbally report their level of discomfort at regular intervals. The range of possible scores ranges from 0 (complete absence of any discomfort) to 20 (severe discomfort). The Misery Scale (MISC)[8], which assigns individuals a score between 0 and 10, also ranks people according to how severely they are affected by their sickness. Motion Sickness Assessment Questionnaire (MSAQ)[9] features fewer questions and more diverse scoring criteria than its predecessor. In addition, a wide variety of trustworthy measurement questionnaires are also being utilized.

Table 1.1 Major subjective measurements[3]

Questionnaire	Rating scales	Reference
SSQ	4-point	Kennedy et al. (1993)
FMS	21-point	Keshavarz and Hecht (2011)
A forced-choice question	Yes or No choice	Chen, Dong, et al. (2011)
MISC	11-point	Bos et al. (2010)
Task performance	-	Freitag et al. (2016)
Average ride time	-	Whittinghill et al. (2015)
Dropout	-	Park et al. (2006)
Motion Sickness Assessment Questionnaire (MSAQ)	9-point	Gianaros et al. (2001)
VEPAB (Virtual Environment Performance Assessment Battery)	-	Lampton et al. (1994)

Despite its limitations—which include the inability to monitor the user's experience in real time, an excessive reliance on subjective judgment, and individual judgment disparities—subjective measurement provides a clearer and more accurate evaluation of the user's experience. This is the case despite the fact that it has limitations.

1.3.2 Objective Measurements

Due to the shortcomings of the competent measuring approach, which include the inability to monitor in real time, an excessive reliance on subjective assessment, and the existence of individual judgment variations. Specifically, the inability to monitor in real time, an excessive reliance on subjective assessment, and the existence of individual judgment variations.

In order to circumvent the limitations that come with using subjective measurement, researchers have created measurement tools that can evaluate VR difficulties by watching how the user's physiological state changes.

The researchers came to the conclusion that it is possible to diagnose VR disorders by analyzing the postural sway of VR users or by monitoring changes in electrophysiology. The postural sway, changes in the electrocardiogram (ECG), measurements of the eyes, the electroencephalogram (EEG), and other signals were the most common physiological markers (e.g., EEG, skin conductivity, respiration, etc.).

Table 1.2 Major objective measurements[3]

Measurements	**Reference**
Postural sway	Palmisano et al. (2018)
	Lubeck et al. (2015)
	Stanney et al. (1999)
	Draper et al. (2001)
	Stoffregen et al. (2017)
Electrocardiogram (ECG)	Kiryu et al. (2007)
	Y. Y. Kim et al. (2005)
Electrogastrogram (EGG)	Farmer et al. (2015); Y. Y. Kim et al. (2005)
Eye-related measures	Y. Y. Kim et al. (2005)
	Diels et al. (2007)
	Yang and Sheedy (2011)
	Howarth (1999)
Electrodermal activity (EDA)	Dennison et al. (2016); Y. Y. Kim et al. (2005)
Electroencephalogram (EEG)	Y. Y. Kim et al. (2005)
Photoplethysmogram (PPG)	Y. Y. Kim et al. (2008, 2005)
Respiration pneumogram (RSP)	Dennison et al. (2016); Y. Y. Kim et al. (2005)
Skin temperature (SKT)	Harvey and Howarth (2007); Y. Y. Kim et al. (2005)
Blood pressure	Farmer et al. (2015)

1.4 Problem Statement

1.4.1 VR developing and VR sickness

Virtual reality will continue to gain popularity as technology develops. According to certain forecasts, the value of the worldwide virtual reality industry would increase to more than $12 billion in 2024, from a forecasted value of less than $5 billion in 2021. Because of this, the number of people who utilize virtual reality will experience a meteoric rise over the course of the next few years.

However, VR users may experience feelings of VR sickness at times, particularly when they are experimenting with it for the first time. This has a severe detrimental influence on the user experience and prevents users from fully immersing themselves in the virtual world. Virtual environments, on the other hand, offer one of their benefits in the form of immersion. Therefore, experiencing VR sickness can hinder users from reaping the benefits of virtual reality. In a more serious vein, VR sickness is likely to cause users significant discomfort in their bodies. If, despite making multiple attempts, users are unable to adjust to the virtual reality environment and continue to experience VR sickness symptoms, this will dramatically diminish users' interest in VR and may even cause them to become terrified of it. This has a significant and detrimental effect on the progress of VR as well as its marketing.

Future VR development will be exceptionally quick, which presents both a big opportunity and problem for developers. More requests from the public will need to be met by the new generation of VR. First, VR will become more prevalent and used in more areas of our lives. VR must therefore be able to satisfy and adapt to a wider range of users. The user experience will be significantly impacted if there are VR sickness symptoms, hence it is critical and necessary to address these issues. Additionally, as VR technology advances, the VR environment's scene will appear more lifelike. For instance, higher quality software scenes will be displayed on the hardware, and modeling and rendering will be improved. However, background research indicates that more realistic sights may cause more severe VR sickness symptoms. In order to effectively address the issue and thereby advance VR, it is therefore important to assist users in adjusting to the VR environment by reducing VR sickness symptoms. Movement inside the virtual environment is also crucial as the metaverse expands and more individuals enter this VR virtual world. Movement in the metaverse might cause VR sickness symptoms, and the loss of user support will delay the advancement of this technology if a lot of users experience movement. Users' ability to move around in VR surroundings can be made easier, which will help the technology spread and be used in new contexts.

VR development requires user support in addition to manufacturer innovation. To draw more consumers to the sector, manufacturers will, on the one hand, continue to deploy VR in fresh contexts or provide more compelling content. However, users will only keep using and purchasing VR items if they are interested in the technology and enjoy the ease and entertainment it offers. The user experience and interest in VR will be significantly impacted if there are unmanageable VR sicknesssymptoms. When using VR for the first time, a new user who experiences severe VR sicknesssymptoms will not only find the experience less enjoyable, but some users may also decide to stop using VR as a result. A strong user base for VR may be built upon the basis. If adaptive training can be used to help people lessen their VR sicknesssymptoms, we can not only make VR more enjoyable for current users, but we can also make VR more fun for new users by enabling them to get used to it more quickly and easily. This will increase the pool of potential VR users and help the VR industry grow from the user level.

Additionally, even though this study is an exercise in adaptation for single users to help those with VR sicknesssymptoms, VR developers and designers can also benefit. When creating new VR content, developers won't need to set any content restrictions because they won't need to worry about consumers acquiring sickness if they are well suited to varied VR environments. Developers are able to produce ever-exciting material.

1.4.2 The difficulty of solving the VR sickness problem

The vast majority of VR hardware and software developers are now working on ways to mitigate the sickness that can be caused by VR. Numerous studies have been carried out in regard to VR sickness[33][34][35], and the overarching purpose of these studies is to investigate and investigate the causes of VR sickness in the hopes of preventing its development. VR hardware manufacturers attempt to lessen the likelihood of users experiencing VR sickness as a result of the performance of hardware devices by continuously advancing technology and production standards, as well as enhancing the performance of hardware. For example, lowering latency[20] and raising frame rate[21] are two examples of ways in which VR hardware manufacturers try to improve performance. Instead, those who work on virtual reality software are trying to come up with content that is less likely to cause users of the device to experience VR sickness. However, there are individual variances in VR sickness, which means that some people may be able to use VR well without needing to acclimate and without feeling VR sickness. However, some people are extremely sensitive to the virtual reality environment, and despite the best hardware and software settings, they are still unable to adjust to the potent VR sickness symptoms that result from the virtual reality environment. This is because these people have personal reasons for being unable to adjust to the VR sickness symptoms. In this particular scenario, relying just on the enhancement of already available VR technology is not sufficient to eradicate all instances of VR-related VR sickness.

It is of the utmost importance to propose specific, targeted solutions for each individual VR user, for each individual VR sickness condition, and for each individual circumstance, as opposed to the existing answers to the VR sickness problem for all users, which ignore the individual distinctions in VR sickness.

VR sickness caused by a difference between the visual input and the vestibular system is one of the principal causes of this type of VR sickness. In addition, this matter is one in which individual differences are highlighted to the greatest extent. As a consequence of this, it is very necessary to provide each user with assistance in becoming adaptedto and adjusting to the VR sickness that is caused by the difference between having a vestibular system and a signal difference. At this time, the market does not offer such a thing for purchase.

The purpose of this research is to develop an adaptive system with the intention of assisting users in more rapidly adjusting to the VR sickness symptoms that are brought on by the VR environment. VR sickness generated by virtual reality headsets should be made less uncomfortable for users so that more people may benefit from the entertainment and practicality that VR has to offer. It will expand the market for virtual reality, raise consumer interest in VR, and move VR advancement and marketing forward.

2 PURPOSE

2.1 Enhance VR Experience and Promote VR Development

The development of a novel treatment for VR sickness is the objective of this research. It will be in a position to foster the expansion of the VR industry and boost the size of the VR market. It will also help users to swiftly adjust to shifting scenes in the virtual environment, minimize the discomfort caused by virtual reality sickness, and make VR more pleasurable for everyone. As a consequence of this, virtual reality will become more widely adopted in a variety of fields and will become more applicable to people's everyday lives.

This research would improve the experience of utilizing VR by easing the symptoms of sickness. Existing VR users can benefit from adaptive training by becoming more accustomed to a wider variety of VR walking scenarios. Adaptive training can assist new VR users become used to the technology more quickly, feel less discomfort while using it, and develop a greater interest in it. In addition, the availability of adaptive training can lessen the dread of VR sickness symptoms, which prevents many users from using VR due to this anxiety. VR can therefore increase the number of users and attract more potential users, increasing interest in VR and its use. VR can support the growth of the VR business and ensure the stability of the VR user base.

2.2 Realize Adaptive Training to Reduce VR Sickness

This research provides a system for VR adaptive training to aid more users, particularly rookie users of VR, in lowering the symptoms of sickness so that users can enjoy VR. The goal of this work is to increase the number of people who can benefit from using VR. This technology enables users to gradually acclimatize to the moving environment of VR from low speed to high speed by modifying the movement speed in VR. This helps users to fast adapt to the VR environment in a short amount of time and lessens the discomfort associated with VR sickness symptoms. A tolerance to the sickness symptoms that can occur in virtual reality is developed in order to help users adjust to the VR world's varying movement rates.

This adaptive training system's main objective is to reduce VR sickness symptoms in general. Its primary objective is to aid users in becoming adapted to the symptoms of VR sickness brought on by the navigation speed by progressively raising the speed. Contrary to the user adjusting to the VR environment on their own, this system enables the user to acclimate more rapidly and comfortably. This would reduces the user's fear of VR due to VR sickness and increases the user's interest in VR.

3 RELATED WORKS

3.1 Adaption to VR Sickness

Some researchers had experiments that proved adaptive training can reduce VR sickness symptoms.

One study has looked into whether or whether VR sicknesses, which are brought on by immersion in virtual worlds, might become habitual[10]. They were of the opinion that frequent participation in moving environments would reduce the severity of motion sickness or even eradicate it entirely.

For the experiment, they tested a total of 26 persons, although only 19 of those participants completed the experiment. Every single person indicated that they did not have any vestibular impairment, and the vast majority of them said that they had never utilized any kind of virtual reality equipment. Participants in the experiment saw a video game on a head-mounted display (HMD) that did not track their movements for a total of twenty minutes spread out over the course of five consecutive days.

During the course of the game, the players were given control of a hovercraft, which allowed them to go in whatever direction they desired, including left, right, up, down, and rolling. Throughout each experiment, participants were prompted to verbally rate how queasy they were feeling caused by virtual reality at regular intervals. For the purpose of this study, the Malaise Rating (MR) Scale was utilized to assess VR sickness symptoms. The evaluation process consisted of the following stages: No symptoms， Some symptoms, no nausea Mild nausea， Moderate nausea.

According to the outcomes of the experiment, the participants in the study reported significantly less nausea on day five compared to day one, and the subjects also experienced a delay in the onset of nausea.

As a result, they arrived at the conclusion that habituation does, in fact, take place and that users' ability to acclimate to VR environments can assist in the reduction of illnesses brought on by VR immersion.

In spite of the fact that it is impossible to draw the conclusion that adaptation was the reason of all of the changes in the patients' levels of discomfort during this trial, it is undeniable that adaptation is to blame for a decrease in the intensity of the symptoms of VR sickness. This experiment also demonstrated that the fidelity of the virtual reality screen as well as the participant's perception of their own motion can both heighten the participant's immersion in the virtual environment; however, they can also heighten the negative effects of immersion, such as sickness caused by VR.

In contrast to the first experiment, another researcher has conducted experiments on how the symptoms of sickness caused by immersive images over time[11]. During the course of this inquiry, the sickness symptoms experienced by the user were investigated and evaluated using both subjective and objective data. In addition, high-definition LCD panels, not head-mounted VR equipment, were used to present the immersive images to the people who participated in the research study.

During the course of the trial, human volunteers were shown the exact same video image three times each. A subjective score and a physiological metric called "ρmax" , which is the maximum cross-correlation coefficient between heart rate and pulse wave transmission time and is thought to reflect autonomic activity, were also used to measure the change in severity of the motion sickness that they experienced. Both of these measures were taken into consideration.

In total, there were 21 healthy volunteers in this research. They were subjected to seeing the same video content for a period of three days, which was displayed on an LCD projector. Participants saw movie trailers for a film that was produced in the United States. This movie was shot with a handheld camera that was purposely panning in order to give the appearance that it was more realistic than it actually was. Because of this, the content of this video is very likely to make you feel sick to your stomach. The violent scenes in the film were omitted in order to decrease the film's overall emotional weight.

The individuals' motion sickness was evaluated using a number of different indices, including the physiological index max, which evaluates autonomic activity, and the subjective index TS, which is a self-rating of motion sickness. Both of these indices were used.

The findings indicated that more than half of the test subjects were able to acclimatize to visually induced motion sickness when the same image was shown to them over and over again. This was determined by both subjective and objective indices.

3.2 Effects of Navigation Speed on VR Sickness

Techniques of navigation, also known as locomotion, refer to the means by which users move around inside of virtual reality environments. One of the factors that can contribute to motion sickness in a virtual reality walking interaction environment is the speed of navigation. The reason that increasing navigation speed can cause VR sickness is because it tricks your brain into thinking that you are moving even though your body remains still. Your brain receives conflicting information from your eyes, your inner ears, and your body at the same time. Your brain will experience confusion and disorientation, which will lead to the onset of VR sickness.

There are a number of studies that point to the fact that the rate of movement in the environment of VR sickness having an effect on the VR sickness symptoms that VR experiences.

An experiment was conducted in which 96 Chinese male subjects wore HMD and walked in a virtual environment at different speeds for a period of thirty minutes[12]. The purpose of the experiment was to investigate the impact that navigation speed has on the level of motion discomfort. Eight different speeds ranging from 3, 4, 6, 8, 10, 24, 30, and 59 meters per second. The SSQ was utilized in order to evaluate the subjects' experiences of VR sickness symptoms.

As the experiment progressed, the researchers found that the VR sickness scores of all of the participants significantly increased as the speed increased from 3 m/s to 10 m/s. However, once the speed exceeded 10 meters per second, the scores had a tendency to become more stable.

3.3 The Rationale for This Research Based on Related Works

Related works have shown that VR sickness can be adapted. In addition, based on our daily experience, the majority of present VR users are spontaneous and have successfully adjusted to the technology after a difficult period of adjustment. However, due to the individual differences in VR sickness symptoms and the fact that some people can adapt to VR sickness symptoms fastly, but some people may be too sensitive and the process of VR sickness symptoms may be too painful. In order to aid people in more rapidly and easily adjusting to VR sickness symptoms, this system was created.

Additionally, research have revealed that the user's VR sickness symptoms are impacted by navigation speed. The symptoms of VR worsen as the navigation speed increases. In order to help users gradually adjust to the various speeds of VR mobile settings and lessen VR sickness symptoms, an adaptive training system for VR sickness was developed, which measures the user's VR sickness symptoms in the virtual world while gradually increasing the navigation speed.

4 SYSTEM DEVELOPMENT

4.1 System Concept

We are aware that one of the key contributors to VR sickness is the discrepancy between the vestibular system and the visual signal, with the optical flow produced by movement in the VR environment serving as the primary cause of this discrepancy. The body produces symptoms of VR sickness when the vestibular system does not receive information that matches the sexual visual signal when the user moves in the VR environment because the visual nerve receives the signal that the body is moving but the vestibular system perceives the information that the body is not moving. By assisting the user in adjusting to the movement in the VR world, this system chooses to delay the symptoms of VR sickness.

According to related study, VR sickness symptoms are thought to be more likely to manifest themselves the faster the movement is in the VR environment. As a result, this method enables users to move randomly within the VR world at various navigation speeds in order to gradually adjust to varied navigation speeds to lessen the severity of VR sickness symptoms as well as their frequency. The system can changing the navigation speed flexibly while observing the user's situation.

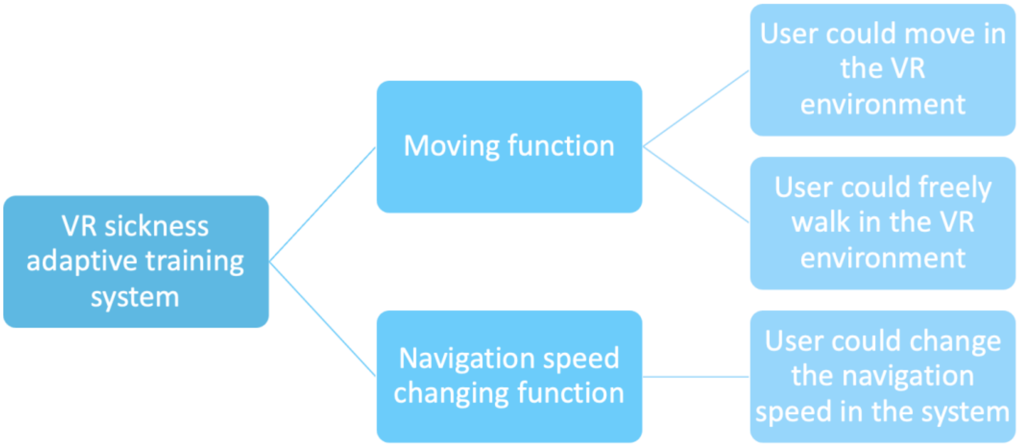

Figure 4.1 The main structure of the system

Figure 4.1 illustrates the two main capabilities of this system, which are navigation speed change and movement. For the movement function to be achieved, a moving subject and a walking environment are first required. The user is the moving subject in this VR environment; the user will be the first view. The moving environment must also have a reference that gives consumers the impression that they are moving. The moving environment must also be sufficiently large to allow the user to walk in a straight path for an extended period of time and to prevent boredom while using it.

Another crucial component of the system is the ability to change the navigation speed flexibly. A user interface is required to ensure that the user may control the navigation speed independently, and the program must be written to do so in order to implement and use this functionality.

4.2 Moving Function

In order to achieve the objectives of being able to adjust the user to different navigation speeds within the virtual reality environment. Unity, a popular piece of software for developing virtual reality experiences, was utilized in the construction of this system.

Changing the navigation speeds flexibly at which the users travels through the VR environment is one of the most critical uses for this system. The user will be able to freely navigate the VR setting due to the fact that the system built in Unity can be loaded with Oculus components.

The Unity system is compatible with Oculus gear, and once OVR Player controller components have been installed, you will have control over the individual components of the device. After the movable subjest has been established as the primary focus of the system, the camera should then be moved to follow the subject. The user will be able to see the range that was acquired by the camera in the system through the display of the Oculus Rift. Additionally, include the components of the two controllers, as well as the functions that correspond to those components. The configuration of this system is such that the controller held in the left hand is responsible for movement and halting, while the controller held in the right hand can rotate the direction. In addition, the user interface may be operated with both hands in order to make adjustments to the speed.

Figure 4.2 The OVR Player Controllor Setting

So that users can have the most authentic experience possible while strolling about inside the virtual reality environment. In order to generate things like highways, buildings, and road signs in the virtual reality environment, 3D models are used. These items can serve as references for the user, assisting them in getting a better sense of the various navigation speeds. While this was going on, the models were being mapped and rendered in order to make the visuals look more realistic and to heighten the user's sense of immersion.

In the process of constructing the VR environment, in order to ensure that in the process of adaptive training it is possible to be constantly walking for a long time. The 3D model is larger, for a town town interspersed with roads, while the road is set up on both sides of a variety of different buildings (Figure 4.3 and Figure 4.4). This was done in order to ensure that in the adaptive training process it is possible to be constantly walking walking for a long time. This ensures that the user does not find the adaptation training to be overly monotonous and hence maintains their interest in the system.

Figure 4.3 3D modle of the VR environment (aerial view)

Figure 4.4 Scenery of the adaptive training system

4.3 Navigation Speed Changing Function

The user is able to maintain a constant walking speed within the virtual reality environment so that they can attain their goals. It is necessary to write code in the c# programming language in addition to the system's original support for Oculus Rift and the settings that can be made.

This is done in order to achieve the setting of the user's movement speed, which ensures that the user will always move at the same consistent speed throughout the experience (Figure 4.5).

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class MyMove : MonoBehaviour
{
    public float speed=1;
    private CharacterController character;
    private bool ReadyToSnapTurn;
    // Start is called before the first frame update
    void Start()
    {
        character = GetComponent<CharacterController>();
    }

    // Update is called once per frame
    void Update()
    {
        if (OVRInput.Get(OVRInput.RawButton.LThumbstickUp))
        {
            character.Move(speed*Time.deltaTime* this.transform.forward);
        }
        if (OVRInput.Get(OVRInput.RawButton.LThumbstickDown))
        {
            character.Move(speed * Time.deltaTime * (-this.transform.forward));
        }
        if (OVRInput.Get(OVRInput.RawButton.LThumbstickLeft))
        {
            character.Move(speed * Time.deltaTime * (-this.transform.right));
        }
        if (OVRInput.Get(OVRInput.RawButton.LThumbstickRight))
        {
            character.Move(speed * Time.deltaTime * this.transform.right);
        }
        if (OVRInput.Get(OVRInput.RawButton.LShoulder))
        {


        }

        if (OVRInput.Get(OVRInput.RawButton.RThumbstickRight))
        {
            if (ReadyToSnapTurn)
            {
                transform.localEulerAngles = new Vector3(0, transform.localEulerAngles.y + 45f, 0);
                ReadyToSnapTurn = false;
            }
        }
        else if (OVRInput.Get(OVRInput.RawButton.RThumbstickLeft))
        {
            if (ReadyToSnapTurn)
            {
                transform.localEulerAngles = new Vector3(0, transform.localEulerAngles.y - 45f, 0);
                ReadyToSnapTurn = false;
            }
        }
        else
        {
            ReadyToSnapTurn = true;
        }
    }
```

Figure 4.5 The code to realize navigation speed changing function

Considering that this technique was built on the basis of the fact that VR sickness can occur in a variety of different individual circumstances. As a result, this system is intended for individuals; hence, it is essential to recognize that the user is solely responsible for determining the movement speed while utilizing the system. Therefore, the operating page that the user sees is also highly significant.

Figure 4.6 The User Interface to change the navigation speed

But the user's ability to become immersed in the experience will suffer as a result of the operation meeting since the user interface is not a component of the virtual reality setting. Therefore, in order to avoid the User interface immersion reduction, minimize the User interface that will modify the movement speed, set the mode so that the position cannot be moved, and set the position to its starting point. Once the user has set the navigation movement speed, the User interface will not be shown while the user is walking ahead.

In addition, when the user is interacting with the User interface, it may also assist them in becoming adapted to the way VR is operated. Users may find that this offers some very limited relief from the symptoms of sickness brought on by virtual reality.

5 EVALUATION OF SYSTEM

5.1 Experimental Design

5.1.1 The Purpose of Experiment

The purpose of this research is to verify the system for training adaption to virtual reality sickness. It was feasible to establish that the system was successful in alleviating the symptoms of VR sickness by contrasting the SSQ scores of the test subjects before and after they used the system.

In their research, the conclusion is that there is a discernible increase in VR sickness symptoms as the navigation speed in the VR environment increases from 3 meters per second to 10 meters per second. This finding is supported by the research that was cited before. The signs and symptoms of VR sickness do not become appreciably worse when the navigation speed is increased by more than 10 meters per second.

As a direct consequence of this, the maximum allowed rate of travel during this experiment was determined to be 10 meters per second. It was possible to determine how effective this method is at reducing the severity of VR sickness symptoms by comparing the severity of VR sickness symptoms before and after the subjects moved at a navigation speed of 10m/s during the VR sickness adaptive training. This comparison was done in order to determine how effective this system is.

5.1.2 Apparatus

The following equipment was employed in this experiment to fully realize the functioning and operation of the VR system.

➉ **Alienware m15 R3 P87F**

Table 5.1 Specifications of the Alienware m15 R3 P87F

Processor	Intel Core i7-10750H 6 x 2.6 - 5 GHz, Comet Lake-H
Graphics adapter	NVIDIA GeForce RTX 2070 Moving - 8192 MB, Core: 1260 MHz, Memory: 1375 MHz, GDDR6, 442.94
Memory	16384 MB , 1600 MHz, 19-19-19-43, Dual-Channel
Display	5.60 inch 16:9, 1920 x 1080 pixel 141 PPI, AU Optronics B156HAN, IPS, AUOB98C, Dell P/N: W8KKR, glossy: no, 300 Hz
Mainboard	Intel HM470
Storage	2x Micron 2200S 512 GB (RAID 0), 1024 GB
Connections	4 USB 3.0 / 3.1 Gen1, 1 USB 3.1 Gen2, 1 USB 3.2 Gen 2x2 20Gbps, 1 Thunderbolt, 1 HDMI, 2 DisplayPort, Audio Connections: 3.5 mm combo, Card Reader: MicroSD
Networking	Killer E3000 2.5 Gigabit Ethernet Controller (10/100/1000/2500MBit/s), Intel Killer Wi-Fi 6 AX1650w (ax = Wi-Fi 6), Bluetooth 5.1
Size	height * width * depth (in mm): 19.9* 360.3* 276 (= 0.78 *14.19 *10.87 in)
Battery	86 Wh Lithium-Polymer, 6-cell

⑩ Oculus Rift

Oculus Rift includes a head-mounted display with headphones, left and right Touch controller and two sensors (Figure 5.1). By the HMD, a wide field of view and outstanding visual quality are provided. Touch is a set of tracked controllers that gives users the natural feeling that users virtual hands are actually your own in virtual reality. Whether sitting down or standing up, Rift sensors detect clusters of IR LEDs to translate user's movement into VR.

Figure 5.1 Oculus Rift (HMD, Left and Right Controller, Oculus Sensor*2)

Oculus Rift places some performance requirements on the PC. It can only be utilized on computers with the specified configuration. The requirements can be seen at Table 5.2.

Table 5.2 Oculus Rift Minimum Requirements

Component	**Recommended Specs**	**Minimum Specs**
Processor	Intel i5-4590 / AMD Ryzen 5 1500X or greater	Intel i3-6100 /AMD Ryzen 3 1200, FX4350 or greater
Graphics Card	NVIDIA GTX 1060 / AMD Radeon RX 480 or greater	NVIDIA GTX 1050 Ti / AMD Radeon RX 470 or greater
Alternative Graphics Card	NVIDIA GTX 970 / AMD Radeon R9 290 or greater	NVIDIA GTX 960 4GB / AMD Radeon R9 290 or greater
Memory	8GB+ RAM	8GB+ RAM
Operating System	Windows 10	Windows 10
USB Ports	1x USB 3.0 ports	1x USB 3.0 ports
Video Output	Compatible DisplayPort video output	Compatible mini DisplayPort video output

- ❿ **Timer**
- ❿ **Another PC to Fill in, calculate and record the SSQ**

5.1.3 Impact of Apparatus Performance

It is possible that virtual reality sickness is caused by the setting of hardware equipment. Therefore, while examining the results of an experiment, thoroughly analyzing and taking into consideration the configuration of the hardware might help to limit the mistake caused by the hardware.

⑩ Alienware m15 R3 P87F

The configuration of the computer is particularly significant since the virtual reality glasses that are being used in this experiment are connected to a computer so that the VR software may be executed, calculated, and rendered on the computer before being transferred to the VR glasses. The computer that was used in this experiment is capable of meeting Oculus Rift's requirements.

However, there is a possibility that the running speed is too slow for huge VR landscapes. This is something to keep in mind. In order to prevent VR sickness from occurring as a result of an insufficient computer setting during the trial, which may have resulted in a sluggish screen or a screen that was unclear, etc. The VR system was given a number of trial runs on this computer before it was used in the experiment. This was done both during the development phase and before it. The test showed that the computer was able to calculate and render accurately at low moving speeds (less than 20 m/s), producing visuals that were clear and unaffected by latency in the process. In the event that the subject is moving at a speed that is greater than 20 m/s, the picture is distinct; nevertheless, there is a problem with the rendering speed not being quick enough, and there is a tiny lag and delay in the process of loading the picture before it shows.

Having said that, the majority of this experiment is carried out at speeds of 10 m/s or slower. When the navigation speed is greater than 20 m/s, the screen lag and delay that are produced by the performance of the computer occur. Due to the inadequate setting of the computer, the participant did not experience any symptoms of virtual reality sickness as a result of this experiment. As a result, we are able to reach the conclusion that this computer is capable of functioning well in the experiment.

⑩ Oculus Rift

Common HMDs may be categorized into 2 types: the first is the HMD with its own internal processor, which has its own body for position recognition, transmission, computation, rendering, output, and other activities; the second category is the HMD without its own internal processor. This particular form of head-mounted display is easier to utilize in day-to-day living. However, because its own processor capacity is limited, it is possible that the lack of performance of the HMD itself was the cause of the impact on the experimenter, which caused the experimenter to develop symptoms of VR disease. This was the result of the experimenter's participation in the study. Connecting to a computer serves as the control mechanism for yet another kind of HMD. Calculations, the rendering and output of the screen, and the transmission of the computer-generated image to the head-mounted display (HMD) are all tasks that are carried out by the processor of the computer. Because this type of head-mounted display (HMD) needs additional position sensors to establish the user's position, and because the HMD needs to be linked to the computer in order to perform transmission, this type of HMD is rather inconvenient to use in day-to-day life situations. However, because the computer's processor has more computing power, it can reduce the possibility of a VR disease situation occurring due to the hardware. As a result, this experiment chose the second HMD to conduct experiments in order to minimize the impact that the performance of the hardware would have.

However, because this kind of HMD has a lot of transmission, there is a possibility that transmission will cause latency. Because latency is another crucial factor in virtual reality sickness, it is essential to ascertain whether or not the latency produced by this apparatus will have an impact on the individual being studied.

Prior to beginning the experiment, the latency time of the HMD was measured. This was done in order to prepare for the experiment.There are many ways to measure VR latency. Here we use Video-Based Measurement of System Latency, which is a very simple and easy to use method.

Figure 5.2 VR latency mearsure

As can be seen in Figure 5.2, the measurement method makes use of two cameras in order to concurrently capture the screen that is displayed on the HMD and the screen that is displayed in reality. The hand-held controller is moved, and numerous particular actions are specified as time points throughout the journey so that subsequent analysis and comparison of the two screens will be easier to perform. The background of the screen is configured to display a stopwatch with an accuracy of one millisecond. This is done so that the delay time of the VR device may be easily determined by comparing the difference in the stopwatch numbers displayed on the two screens. The total amount of time delay, which can be determined by taking the average of a substantial amount of data, is approximately 33 milliseconds. In light of previous research and products, it has been determined that a delay of 33 milliseconds is not significant in comparison to other items of its kind. Also, 33 milliseconds is okay for the user. Therefore, despite the setback, it is reasonable to conclude that the virtual reality eye will not have a significant effect on the experiment.

5.1.4 Possible Effects of Other Factors on the Experiment

When the user is in a virtual reality setting that moves, the speed, rotation pattern, and oscillation amplitude can all have an effect on the user's experience of VR sickness. The navigation speed in a virtual reality environment can cause some to experience symptoms of VR sickness, which can be addressed with this system. During the experiment, the participants were instructed to remain seated as much as possible so that they could continue to hold their bodies in a smooth position and limit the amplitude of vibration. This was done to ensure that the variables would remain unique. During the encounter, it is important to maintain one's head still and to avoid turning it in any direction.

Since the most common symptoms of VR sickness include headaches, sweating, nausea, vomiting, and other similar symptoms, etc. These symptoms are not exclusive to virtual reality sickness; rather, the user may experience them due to a combination of VR sickness and other circumstances. It is essential to steer clear of symptoms brought on by the surrounding environment that are analogous to those of VR sickness.

For instance, make sure that the person is not abusing drugs and that their health is in good condition. Before beginning the experiment, the participant is instructed to take a five-minute break in order to ensure that they have a regular heartbeat, a normal body temperature, and that they do not sweat. In addition, before to beginning the experiment, the participants were instructed to remove their masks in order to reduce the risk of breathing difficulties brought on by the masks, which could result in symptoms that are analogous to those of VR sickness. In addition to this, it was assured that the temperature of the room was appropriate in order to prevent the subjects from sweating owing to the high temperature of the room. This is due to the fact that perspiration is also one of the symptoms of VR sickness.

Besides, for the purpose of gathering data in this experiment, a before training needs to be established. Before beginning the acclimatization training, the participants in the study were given the opportunity to observe a fast-paced moving picture in the virtual reality environment. The experimental subjects will feel VR sickness symptoms as a result of this experience. In order to stop this symptom from persisting and to influence the way VR sickness symptoms are measured in the future. Before beginning the formal VR sickness training experience and VR sickness symptom measurement, the participants were instructed to take a break for an adequate amount of time following the VR experience that served as the before training. This was done to ensure that there would be no lingering effects of the VR experience.

5.1.5 Experimental Process Design

The experiment was separated into three main sections: familiarization with the VR environment, evaluation of the before training's performance before acclimatization training, and evaluation of the latter.

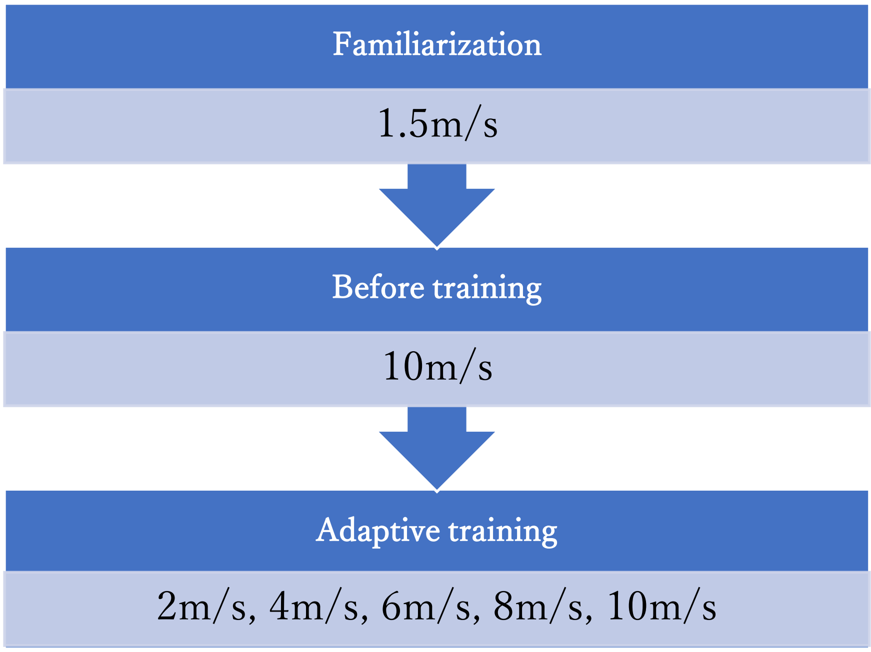

Figure 5.3 Experimental Process Design

For three minutes, the subjects were free to roam around in the VR world at a speed of 1.5 m/s during the VR environment familiarization. In order to avoid the onset of VR sickness symptoms brought on by inexperienced operation, it was utilized to adapt to the operation of the VR environment. There is a purpose behind the 1.5 m/s speed decision. The average human gait is 1.5 meters per second, and this information is frequently used in the creation of VR applications, including VR travel and VR gaming. Nevertheless, 1.5 m/s is a slower speed that is less likely to cause symptoms of VR sickness. At a slower pace, it can enable consumers to fully appreciate the VR environment and this system's operation. A lower speed will be introduced to the VR sickness adaptation training later, though, if the user is still experiencing severe VR sickness symptoms at a speed of 1.5 m/s.

The result assessment of the before training prior to the adaptation training is the second component. After experiencing a 10m/s navigation speed in a virtual reality environment, participants were asked to rate the intensity of their VR sickness symptoms on a questionnaire. This information was compared to the post-training outcomes.

The formal adaption training is the third component. The experimental subjects were set up with fixed speed increments of 2 m/s, 4 m/s, 6 m/s, 8 m/s, and 10 m/s, each of which was experienced for three minutes in order to better examine the experimental data. After each event, participants were asked to complete a questionnaire to rate the intensity of their VR sickness symptoms. However, when using the system alone for adaption training, the users may select the navigation movement speed that was best for them and determine the duration of experience for each speed on their own.

If the subject's SSQ score is excessively high during the experiment, it means they are not coping well with the present navigation speed. To ensure that the user can adjust to the higher speed with good acceptance of the present navigation moving speed, it is required to halt the next experience of raising the speed, drop the speed and re-experience it, and increase the moving speed more slowly.

For instance, the experiment's standard training process used speeds of 2, 4, 6, 8, and 10 m/s. But after the experiment, the person was able to accept the 2 m/s speed. The SSQ score was excessively high following the encounter at 4 m/s navigation speed, indicating that the individual did not adapt to 4 m/s navigation speed well. So, until the subject could tolerate it well, we dropped the speed to 3 m/s, and then progressively increased the navigation speed.

5.2 VR Sickness Measurement

5.2.1 Simulator Sickness Questionnaire (SSQ)

The Simulator Sickness Questionniar (SSQ) is the measure that is utilized the most frequently. The SSQ is comprised of sixteen questions, as illustrated in Figure 5.4; users are prompted to select an answer from a range of zero to three points on a scale that corresponds to the intensity of their symptoms. A score of 0 indicates that there are no symptoms present, 1 indicates slight symptoms, 2 indicates moderate symptoms, and 3 indicates severe symptoms. The SSQ is broken down into three different subscales, including Nausea, Oculomotor, and Disorientation. When a subject has a higher SSQ score, this indicates that they are dealing with a more severe case of VR sickness symptom.

	Weights for Symptoms		
Symptoms	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eye strain		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]

Figure 5.4 Simulator Sickness Questionniar (SSQ)

According to the findings of certain researchers, if the subject's total score on the SSQ is greater than 33.3, it is reasonable to assume that they are in a state of extreme discomfort[13]. However, due to the fact that every individual uses a unique set of standards when evaluating his or her own symptoms, the standard of 33.3 points cannot be applied to every single subject. It is necessary to do an analysis of it within the framework of the current scenario.

5.2.2 Reasons for Useing SSQ As the Measurement for The Experiment

SSQ is a more precise subjective measurement technique. SSQ can assess and obtain precise values for nausea, eye movement, and disorientation in three dimensions at the same time, which is useful for the interpretation of following experimental findings.

SSQ does, however, have significant drawbacks. First, it is unable to assess patients' sickness symptoms in real time. The results of this experiment won't be impacted by the inability to monitor the subject's experience in real time because the duration of the experiment is fixed. The test subjects also complete a questionnaire and make a subjective assessment of their own position in order to receive the results. Since each person views himself uniquely, so too can their assessment of how seriously their own VR sickness symptoms have affected them. This has a lot to do with how well-adapted and resilient each person is. However, this approach was first created for individual disparities because VR sickness itself has individual variations. As a result, the analysis of the final results involves contrasting the measurement results of one user with those of other users. It will have no impact on the experiment's outcomes as long as each subject's personal standard is maintained uniformly.

At the same time, the subjective measuring technique, which merely calls for completing a questionnaire, is easy to use. the technique used to evaluate supervisors. Spend some time filling out, volunteers are required outside of the VR environment. Users can focus on their own emotions and make better assessments of their own condition and VR sickness symptoms after removing themselves from the VR experience.

The objective measuring approach necessitates wearing physiological monitoring equipment for the subject as well as monitoring the subject's body. The subject's emotions throughout this procedure could be impacted by the pressure, weight, and substance of the physiological monitoring equipment.

In conclusion, the advantages of accuracy and convenience of subjective measurements. However, this experiment is unaffected by a few drawbacks of subjective measurement. As a result, the SSQ questionnaire was chosen to quantify and examine the VR sickness symptoms experienced by the experiment's participants.

5.3 System Verification Experiment

5.3.1 Participant

There were 11 participants in this experiment. All experimental participants were physically healthy and had no dysfunction of the vestibular system.

5.3.2 Experiment Procedure

The participant entered the test area then. First, take five minutes to relax to ensure that their body is in good condition, that their temperature is normal, that they are not sweating, having breathing issues, feeling uncomfortable, or anything else. The methodical, adaptable workouts were then initiated, including walking in the virtual reality environment at a navigation speed of 1.5 meters per second, getting used to the weight of the VR glasses, getting used to using the VR handle, etc. After that, the SSQ subjective measurement survey was completed.

The subjects were then instructed to move at a speed of 10 meters per second for three minutes. The SSQ questionnaire was completed following the experience as a baseline for comparison between before and after the acclimatization training. The patients were subsequently instructed to take a longer-than-10-minute break. It is ensured that all VR sickness symptoms brought on by this encounter vanish and have no bearing on the trials and measurements that follow.

The official VR sickness adaption training will then start. Each of the five speeds—2, 4, 6, 8, and 10 m/s—that the patients would encounter was supposed to last three minutes. Each event will be followed by the completion of the SSQ questionnaire.

The experiment was completed by eight participants with success after they followed a flow at rates of 2, 4, 6, 8, and 10 meters per second. During the adaption training, two of the subjects developed significant sickness symptoms when traveling at a particular pace. Because of this, we decreased the speed from the point at which the individuals started experiencing sickness symptoms. We gradually raised the pace of the navigation speed when the individuals demonstrated that they were able to tolerate it properly.

Figure 5.5 The scene of experiment

During the virtual reality environment experiment, there was another participant who achieved an exceptional SSQ score while moving at a pace of 1.5 meters per second. It was determined to be a case of VR sickness since the experimenter in question was a first-time user of virtual reality (VR) equipment and was therefore unfamiliar with the VR environment. This experimenter's training speed was therefore enhanced by 0.5, 1, and 1.5 m/s of experience respectively as a result. After three iterations of the virtual reality (VR) experience, the participant was able to adjust to the setting to the point that he could continue completing the experience at speeds of 2, 4, 6, 8, and 10 meters per second.

After the participants had gone through all of the events, we asked them to fill out the questionnaire that would be used to evaluate the system.

5.4 System Validation

The purpose of this questionnaire is to conduct a system validation. The primary purpose of this questionnaire is to collect some fundamental information about the participant, such as their gender, age, previous experience with virtual reality (VR), and so on. It also covers the subject's thoughts and feelings after going through this adaptive training session. Its primary concentration is on an analysis of the system itself, as well as the emotions that are elicited by the system. We can judge whether this system is effective and satisfactory based on the feedback from the subjects, and we can determine whether it can help others to reduce the pain and distress caused by VR sickness symptoms. This is something that can be seen through the use of this questionnaire, which allows us to find out whether or not the subjects are pleased with this system.

First and foremost, some general information on the users. owing to the fact that factors such as gender, age, and prior experience with virtual reality can all have an effect on the sickness experienced in VR. As a result, questions concerning respondents' gender, age, and prior experience with virtual reality (VR) were included in the questionnaire. Additionally, the participants were asked if they had any interest in virtual reality (VR).

The evaluation of the virtual reality sickness training system was the subject of the second section of the questionnaire. This included questions about whether or not they liked the VR environment, whether or not they found this system easy to operate, whether or not they could feel the different movement speeds in VR, whether or not they felt the VR sickness symptoms reduced, whether or not they felt they enjoyed the entire adaptive training process, whether or not they felt that receiving the training increased their interest in VR, and whether or not they thought they could adapt to the VR walking environment.

A 5-Point Likert Scale questionnaire would be used to validate the system. The validation is performed to prove that this system can match the requires. Therefore, the questionnaire was designed based on the purpose of this research.The questions are as follows:

1. I like the VR environment of the adaptive training system.
2. I thought this system was easy to operate.
3. I can feel the difference in the VR navigation speed.
4. I thought this system did help me reduce the VR sickness symptoms.
5. I enjoyed this experience a lot.
6. My interest in VR has increased after this experience.
7. I think I can adapt to the VR walking environment very well in the future.

Question 1,2,3 was asked about the functionality of this system, whether the subjects like this system or not. Because this system should bring a satisfying experience for the users. Question 4 addresses the main objective of this system by asking whether the user can feel that their VR sickness symptoms are reduced. This question asked the subjects' feeling. Besides, This system would reduce the user's fear of VR due to VR sickness and increases the user's interest in VR. So question 6 ask whether the subjects' interest in VR increased after experiencing the system. Question 7 is talking about the users confidence that they can adapt to different VR environments in the future, which proves that the system can help reduce the user's fear of VR due to VR sickness and increases the user's interest in VR, shows the system can promote the development of VR industry.

6 RESULTS

6.1 System Verification Experimental Results Analysis

6.1.1 Individual Analysis of Experimental Subjects

Due to the individual variability in VR sickness symptoms and the experiment's use of the subjective SSQ questionniar method, there are variations based on subjective evaluations. Therefore, it's crucial to consider how each participant's participation affected the experiment's findings. We may study each participant's experience and the factors unique to them that influenced the experiment's outcomes and learn more about the causes of VR sickness symptoms once we have a complete picture of their individual circumstances.

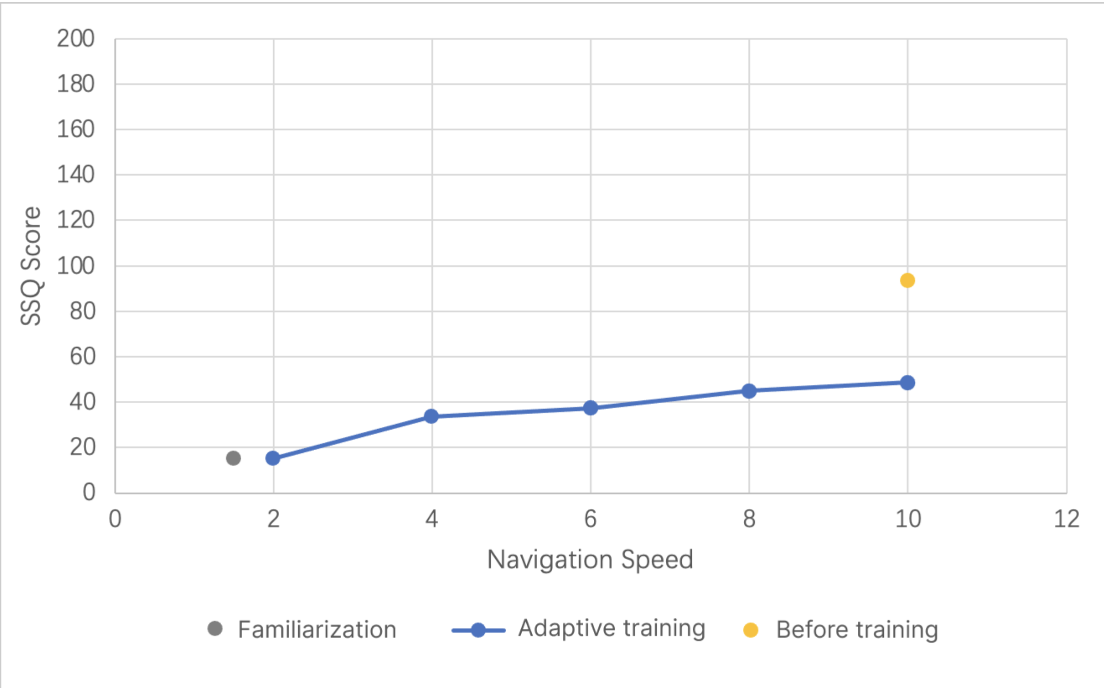

Figure 6.1Experimental result of Subject No.1

Subject No. 1 had VR experience who occasionally used VR in daily life. The user was quite adept at navigating the VR setting. There was minimal VR sickness at a speed of 1.5 meters per second. At a speed of 10 m/s, more acute symptoms of VR sickness were generated. In order to train the test subjects, speeds of 2, 4, 6, 8, and 10 meters per second were used. According to the result, the SSQ scores continued to marginally rise as movement speed rose. However, when compared to the before training, the subjects had reduced VR sickness following the acclimation training, according to his own comments.(Figure 6.1)

Seven additional participants with outcomes similar to subject 1 received adaptation training at speeds of 2, 4, 6, 8, and 10 meters per second. After the adaptation training, they all displayed a great improvement in their VR sickness symptoms. These experiment result can be seen in Figure 6.2-Figure 6.8.

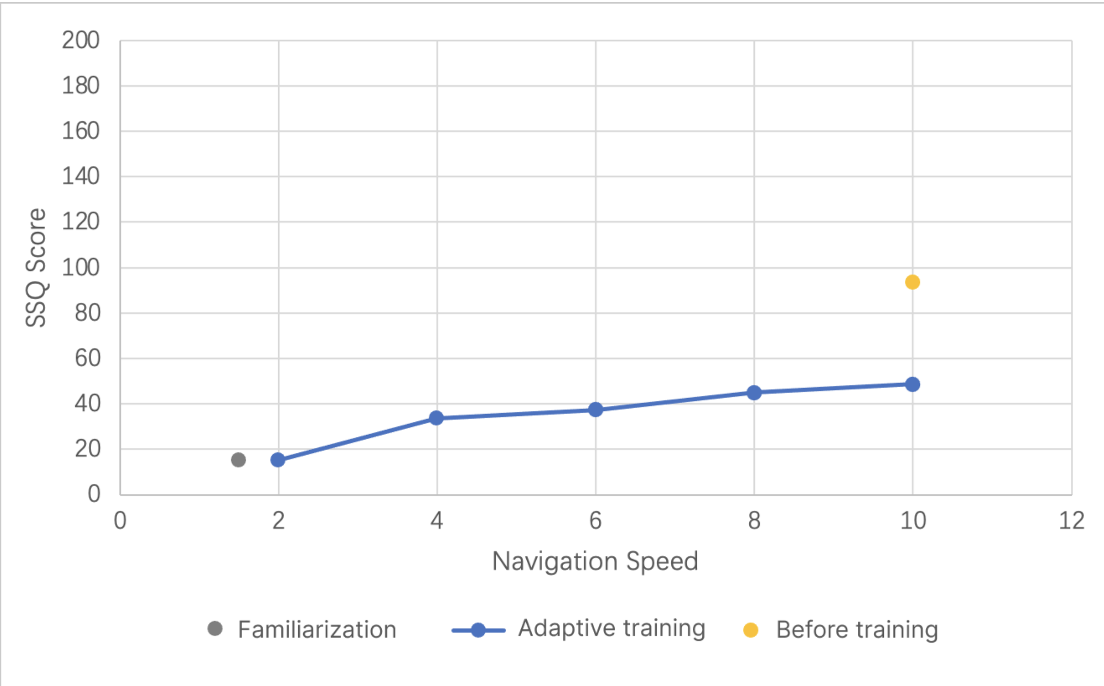

Figure 6.2 Experimental result of Subject No.3

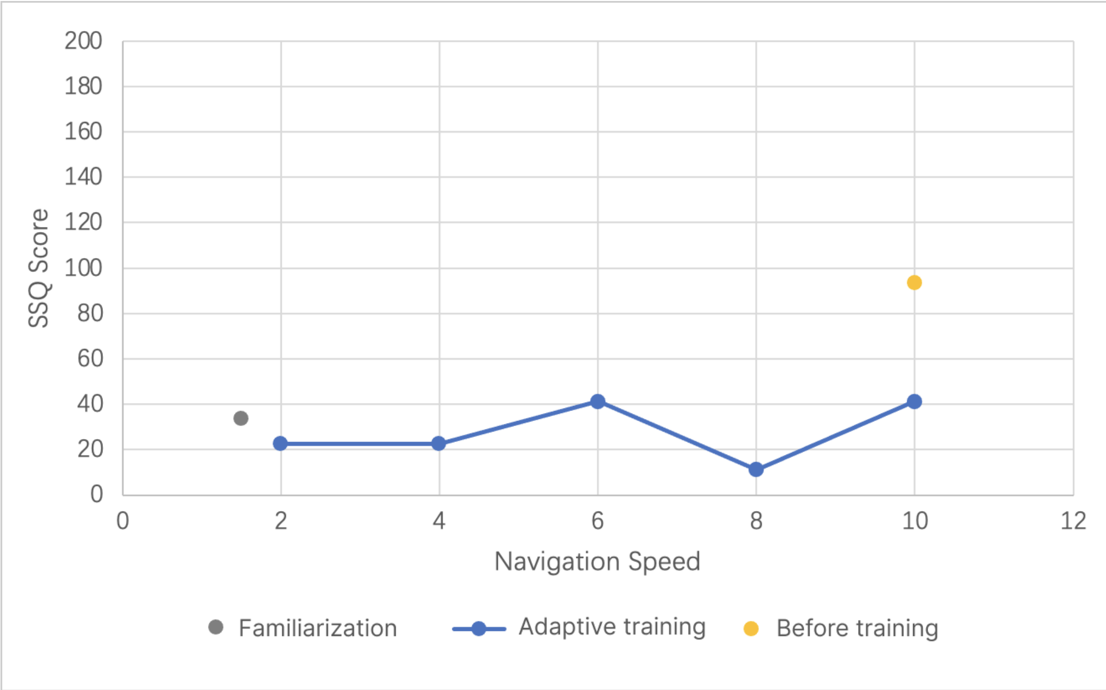

Figure 6.3 Experimental result of Subject No.4

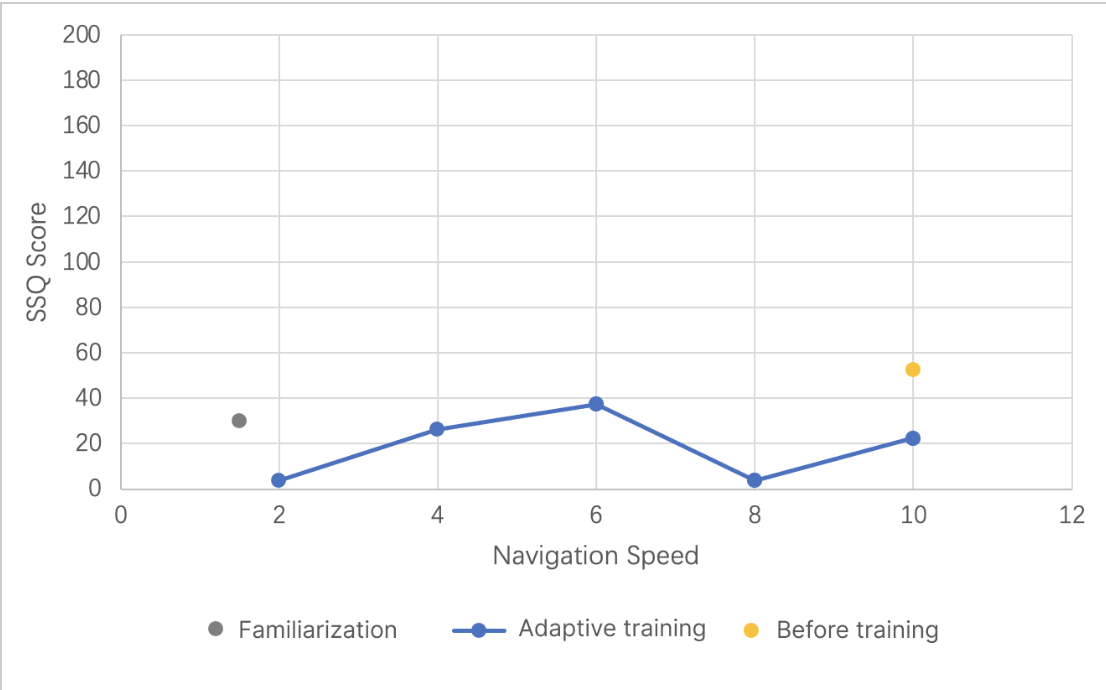

Figure 6.4 Experimental result of Subject No.6

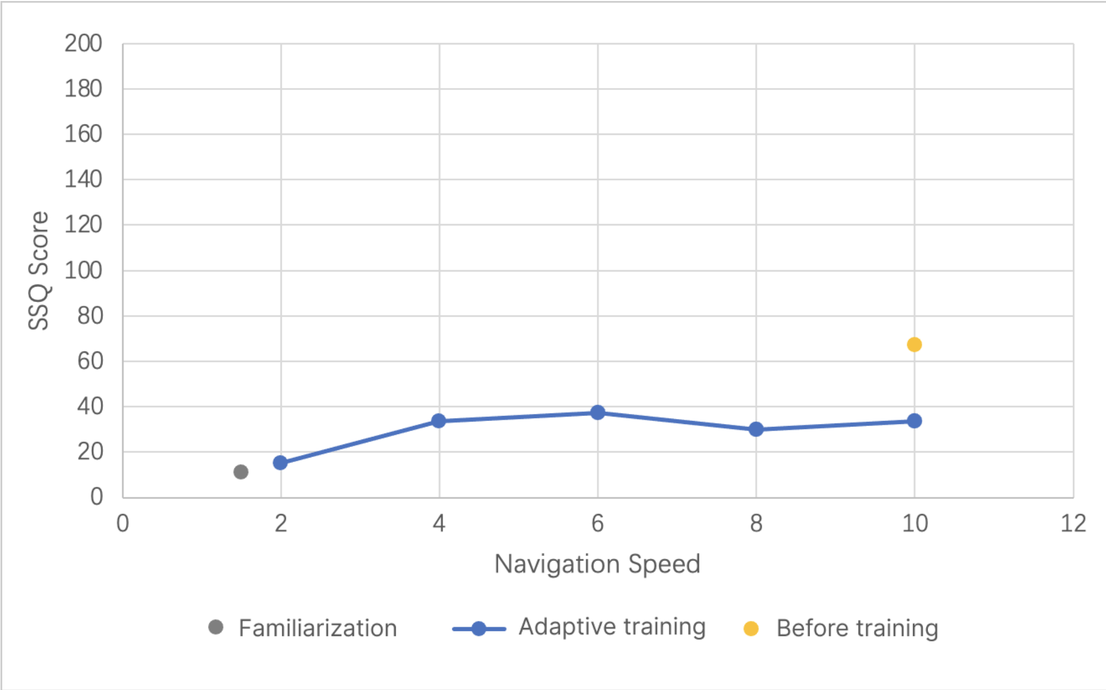

Figure 6.5 Experimental result of Subject No.8

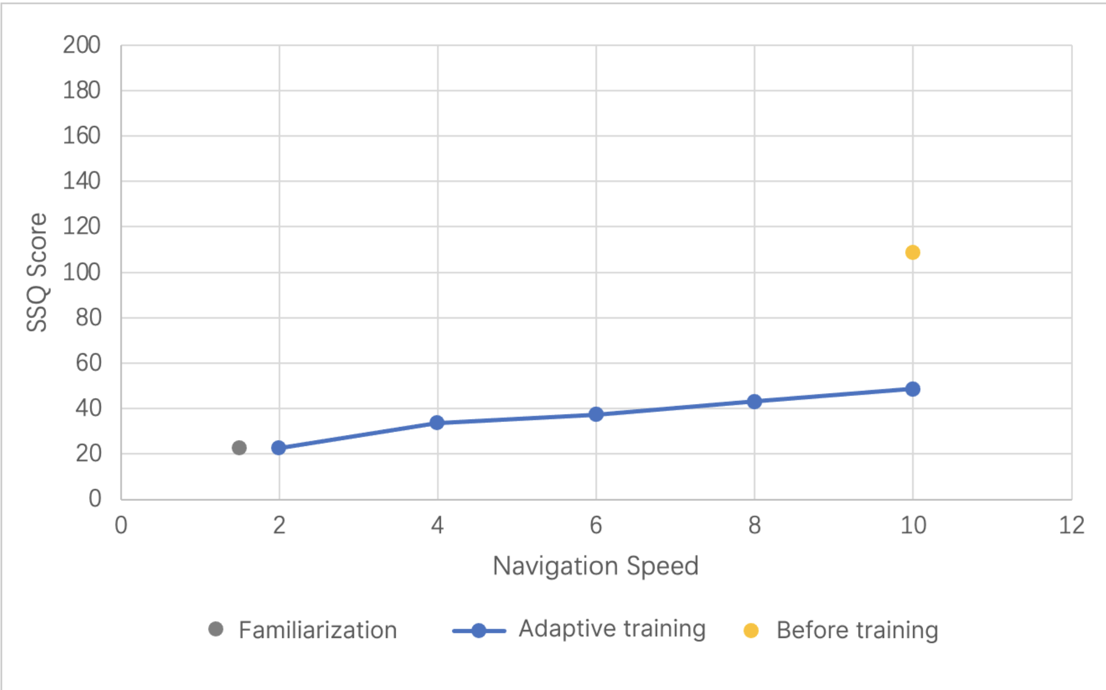

Figure 6.6 Experimental result of Subject No.9

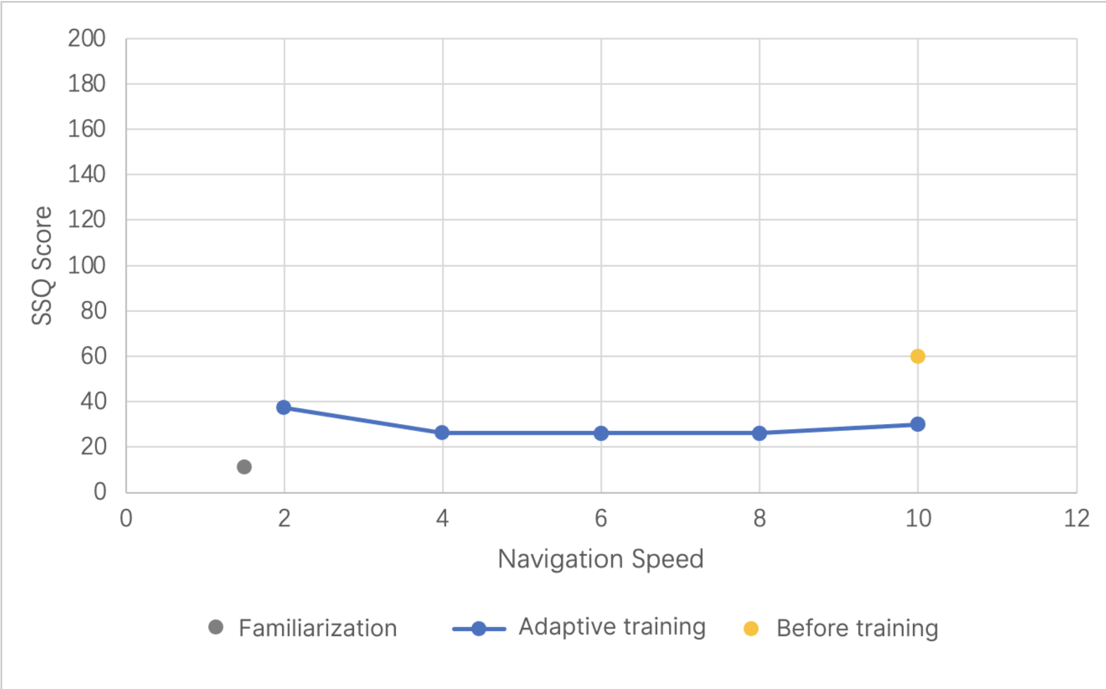

Figure 6.7 Experimental result of Subject No.10

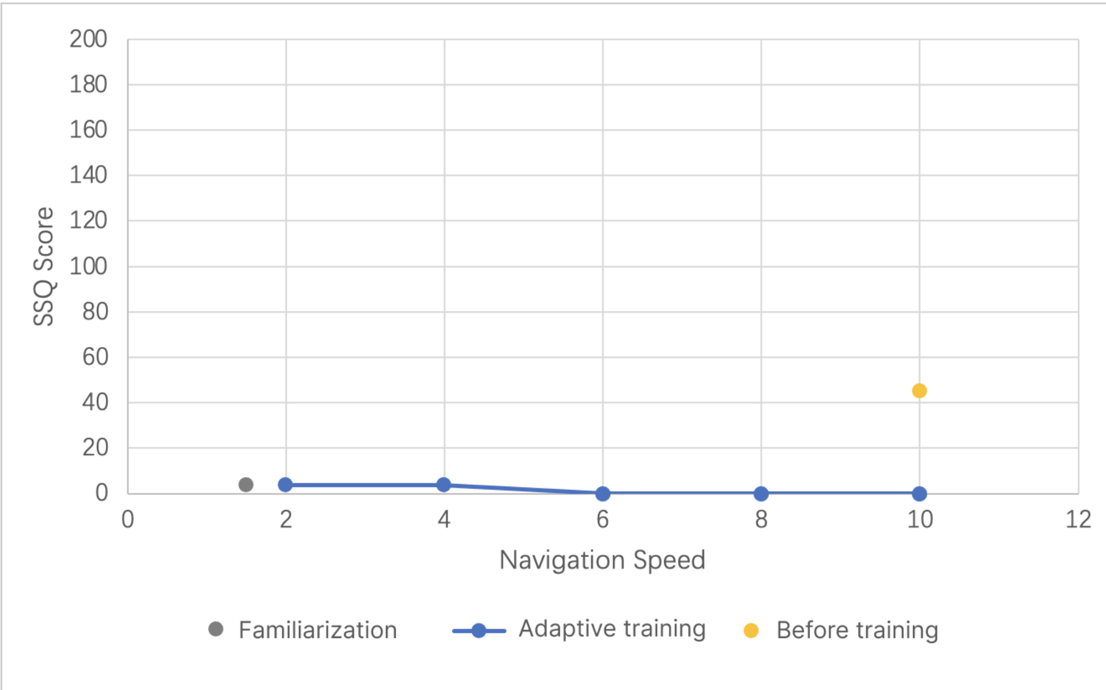

Figure 6.8 Experimental result of Subject No.11

When the adaptation training was increased to four meters per second, Subject No. 2 had an abnormally high score on the SSQ. As can be seen in Figure 6.9, in the subsequent iteration of the experiment, the pace was slowed down to three meters per second. After determining that the subject did not produce an excessive amount of SSQ scores, the training was carried out once more at a speed of 4 meters per second. Subsequently, the navigation speed was gradually increased after it was determined that the subject was able to accept it well. During the ensuing adaptation training, the subject's VR sickness symptoms were within the subject's own personal threshold for what was considered to be an acceptable range. This result was significantly different from the other eight participants who were able to finish the adaptation training satisfactorily. The subject gave evidence that motion sickness was a problem that he or she was experiencing. Therefore, it may be extrapolated that the subject was extremely sensitive to the misunderstanding of the vestibular system system and visual signals, which is what led to the requirement for additional training sessions and prolonged adaption time when the subject was undergoing adaptive training.

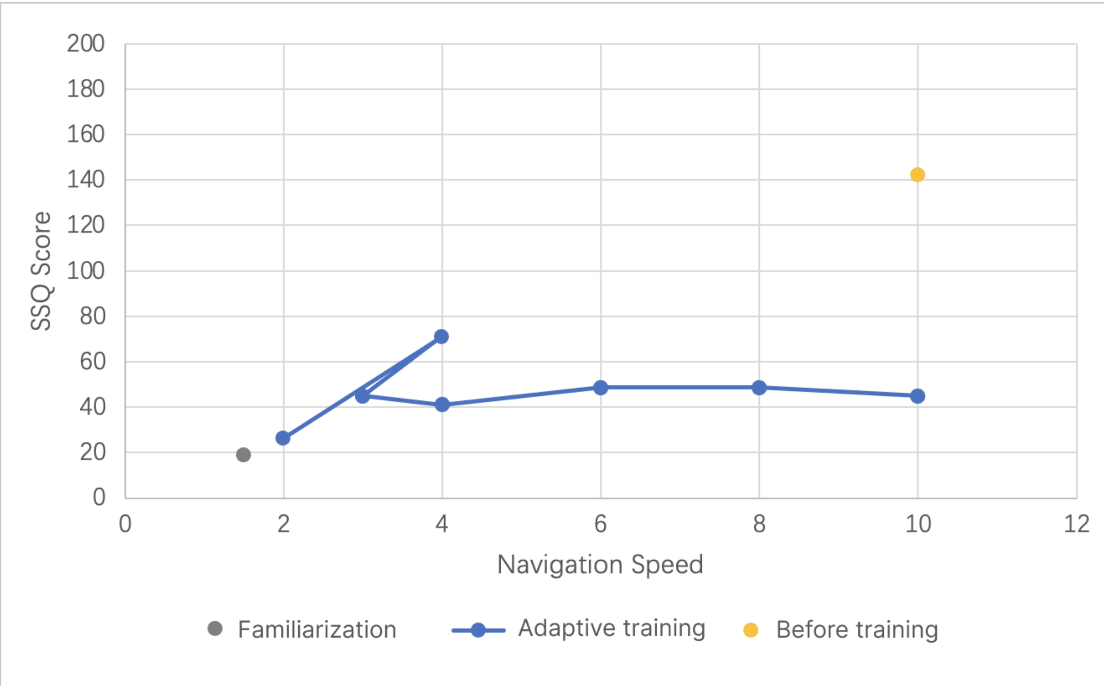

Figure 6.9 Experimental result of Subject No.2

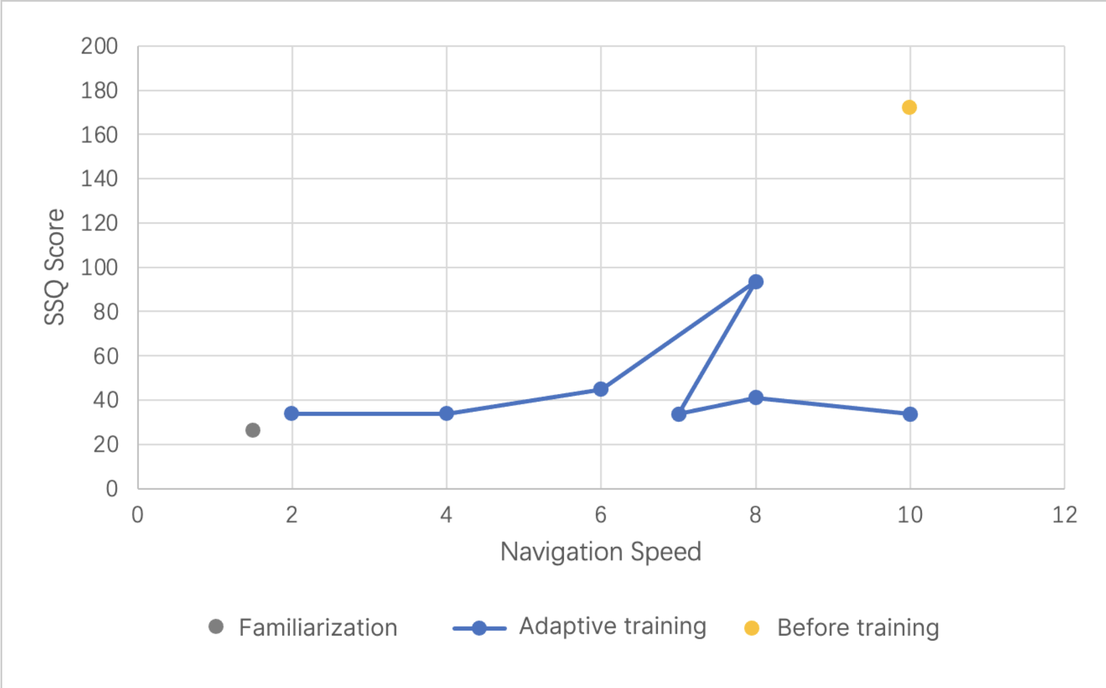

Figure 6.10 Experimental result of Subject No.7

Similar to subject No.2, subject No.7 also experienced excessive SSQ scores during the adaptation training. After adaptation training at a speed of 8 m/s, subject No. 7 got a score of 93.5 on the SSQ. Subject No. 7 expressed through post-experimental communication that she felt the symptoms brought on by each adaptation training session will take some time to go away. As a result, sickness symptoms were becoming worse during successive training sessions. Later in the adaption training, this led to severe sickness symptoms. The duration of VR use does have an impact on the user's sensations of sickness. As a result, we can conclude that subject No. 7's sickness symptoms were vulnerable to the effects of prolonged use.

Additionally, there was a different circumstance. During the VR environment feminization, Subject No.5 displayed extreme VR sickness symptoms at a speed of 1.5 meters per second. He had never used VR technology before, so it's possible that his symptoms of VR sickness were brought on by unfamiliarity with the VR environment and with how to control the VR system. This information led to the addition of three experiences for the subject at the navigation speed of 0.5, 1, and 1.5 m/s. Subject No.5 was able to adjust well to each speed of movement after the subject had fully acclimated to the VR environment. And he essentially did not exhibit VR sickness symptoms at the end.

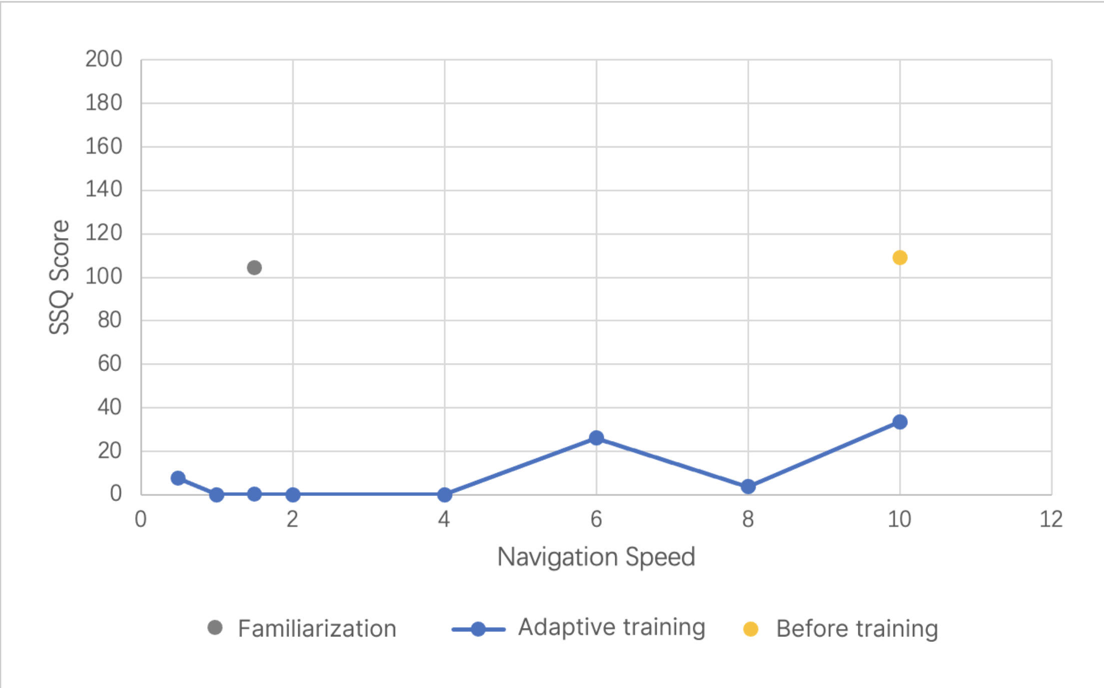

Figure 6.11 Experimental result of Subject No.5

6.1.2 Overall Analysis

In order to verify that this adaptive training system is effective, it is necessary to analysis the examination of both the individual subjects and the overall data.

Table 6.1 Experimental analysis

Subject No.	SSQ (before)	SSQ (after)	Reduction
1	93.5	48.62	44.88
2	142.12	44.88	97.24
3	82.28	44.88	37.4
4	93.5	41.14	52.36
5	108.46	33.66	74.8
6	52.36	22.44	29.92
7	172.04	33.66	138.38
8	67.32	33.66	33.66
9	108.46	48.62	59.84
10	48.62	29.92	18.7
11	44.88	0	44.88
Average			57.46

The SSQ scores of all eleven subjects before and after they underwent adaptation training for VR sickness generated at a speed of 10 m/s are displayed in Table 6.1 so that the results can be viewed side by side. Following completion of the adaptive training, the SSQ scores of all eleven participants were found to have improved. This suggests that this technology is capable of assisting users in adapting to moving within a virtual reality environment and reducing the feelings of sickness that are brought on by having navigation speed.

In addition, statistical analysis was performed by t-test for this experiment. To test whether there is a difference in the SSQ scores of the same user before and after receiving the adaptation training in this experiment. With Excel, t-test calculations were performed on the results of this experiment, and the results are shown in the following Table 6.2.

Table 6.2 t-test

t-Test: Paired Two Sample for Means		
	Before	*After*
Mean	92.14	34.68
Variance	1584.15928	201.67576
Observations	11	11
Pearson Correlation	0.51743057	
Hypothesized Mean Difference	0	
df	10	
t Stat	5.4993165	
P(T<=t) one-tail	0.00013102	
t Critical one-tail	1.81246112	
P(T<=t) two-tail	0.00026204	
t Critical two-tail	2.22813885	

P<0.01, shows that there is a great difference between the before and after data .Which indicates that the system has a considerable effect on alleviating the symptoms of VR sickness.

10 of the experiment's participants are in their 20s, while one is 30s. Theoretically, this investigation can only demonstrate that this approach is efficient for reducing VR sickness symptoms in adults in their 20s. Age also has an impact on the symptoms of VR sickness. The way that different ages react to VR sickness varies. However, getting used to VR sickness is a fact. According to experimental findings from comparable investigations, adaption can indeed assist to lessen symptoms of VR sickness. Additionally, based on our day-to-day encounters, VR users naturally adopted the technology during a period of adaption before this system was created, some for a lengthy period of time and others for a brief one. However, this system's goal is to make the adjustment process better, quicker, and simpler for users. Therefore, this trial was carried out on the 20s age group and demonstrated that this adaptive system can assist people in adapting to the VR world more quickly and easily while also reducing the symptoms of VR sickness.

6.2 System Validation Analysis

A questionnaire that questioned about the feelings following this adaptation experience was used to validate this study. It primarily assesses elements like the system itself and the emotions the system causes. By using this questionnaire to assess the subjects' satisfaction with the system, we can determine whether it is satisfactory or effective in helping others actually alleviate the pain and suffering brought on by VR sickness symptoms. Figure 6.1- 6.7 illustrate the result of questionnaire. In all of the figure the option numbers means: 1-Strongly disagree, 2-Disagree, 3-Undecided, 4-Agree, 5-Strongly agree.

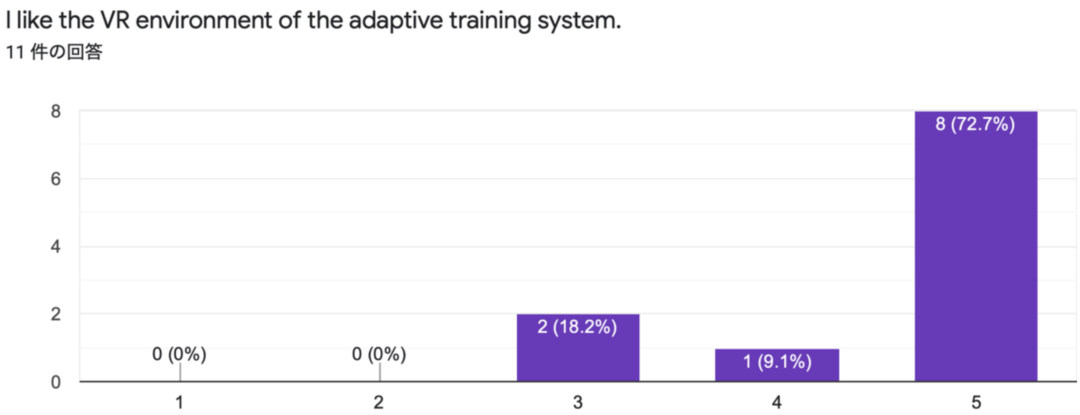

Figure 6.12 Evaluation for the VR environment

Figure 6.1 shows the users' evaluation of the VR environment of this system. 81.8% of users like the VR environment, and two users chose undecided. And the average score is 4.55, which means most people choose strongly agree. This method creates a town's virtual environment using 3D modeling. In order to prevent users from getting bored while designing the virtual world, colorful and varied structures and terrains were developed due to the simplicity of this system's features. This virtual environment is well-liked by the vast majority of users, demonstrating how good it is in this system.

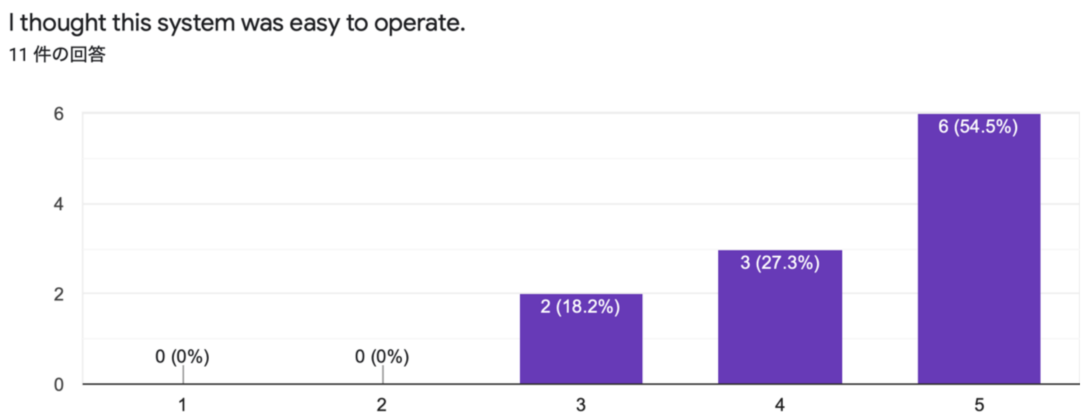

Figure 6.13 Evaluation for the handleability

Figure 6.2 depicts how users rated this system's operability. 81.8 percent of users selected to disagree or strongly disagree with the statement that the system is simple to use. And in the 81.8% of subjects who agree six out of nine subjects strongly agree.This demonstrates how simple it is to control and run this system by selecting the left hand to control forward motion and the right hand to control angle rotation.

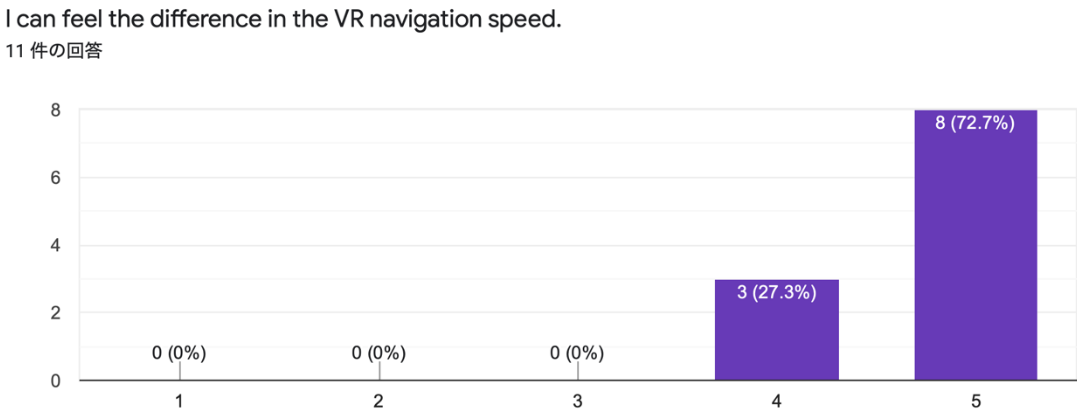

Figure 6.14 Evaluation of navigation speed changing

The user's response on the system's change in pace is shown in Figure 6.3. The movement speed is planned to be controlled, but this technology also enables users to experience various movement speeds by setting up references in the virtual environment. The various traveling speeds are perceptible to all users. And the average score is 4.73, which means most subjects strongly agree.

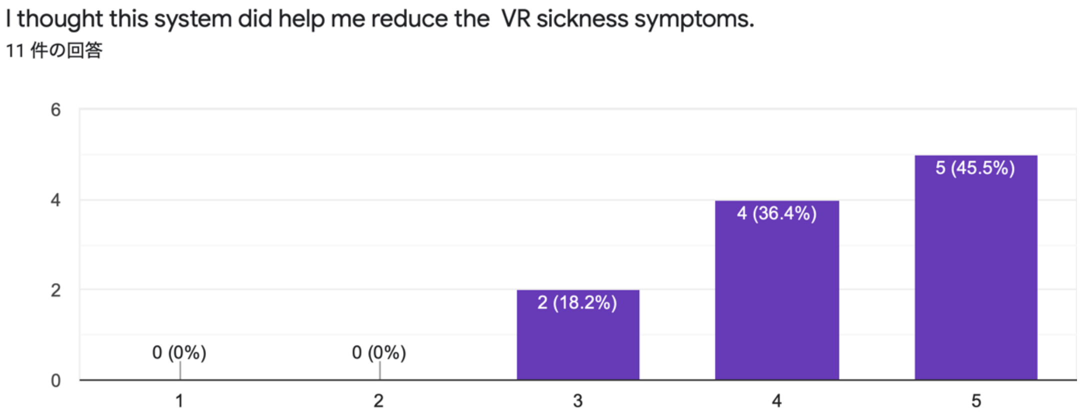

Figure 6.15 Evaluation of the effectiveness

Users' assessments of this system's effectiveness are shown in Figure 6.4. By altering the navigation pace, this method aids users in becoming acclimated to the VR environment and minimizing sickness symptoms. Nine out of eleven subjests were able to clearly perceive how this technique reduced their symptoms of VR sickness.

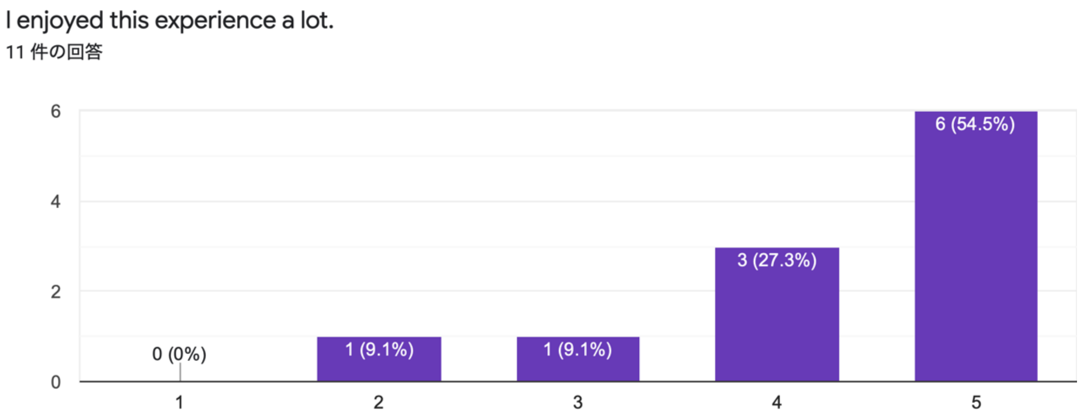

Figure 6.16 Evaluation of the user experiences

Users' assessments of this system's user experience are shown in Figure 6.5. Nine of the eleven subjects reported feeling good, one could not judge, and one reported feeling awful. In the nine subjects who feeling good, there are six subjects strongly agree that they felt good.Given that this system is an adaptive training system for VR sickness symptoms, discomfort throughout the adaptation process is a potential. This approach aims to prevent users from experiencing discomfort while going through the adaption training phase by gradually raising the navigation speed. According to 81.8% of users, this system offers a satisfactory user experience. Average score is 4.27.

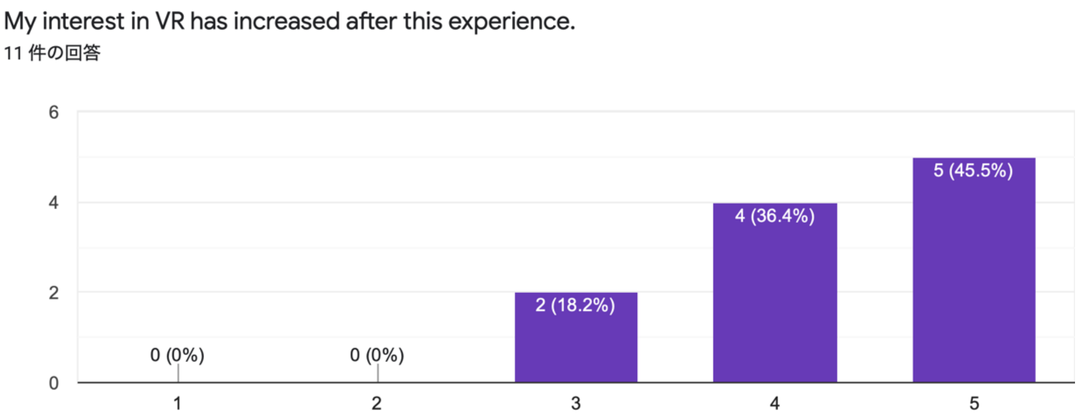

Figure 6.17 Users interest in VR

Figure 6.6 demonstrates if users' interest in VR grew as a result of using this method. The goal of this test is to demonstrate how this method can raise users' interest in virtual reality by decreasing their VR sickness symptoms. Following their use of this technology, 81.8 percent of users reported having a greater interest in virtual reality (45.5% strongly agree and 36.4% agree). It demonstrates how effective this system may be in advancing VR.

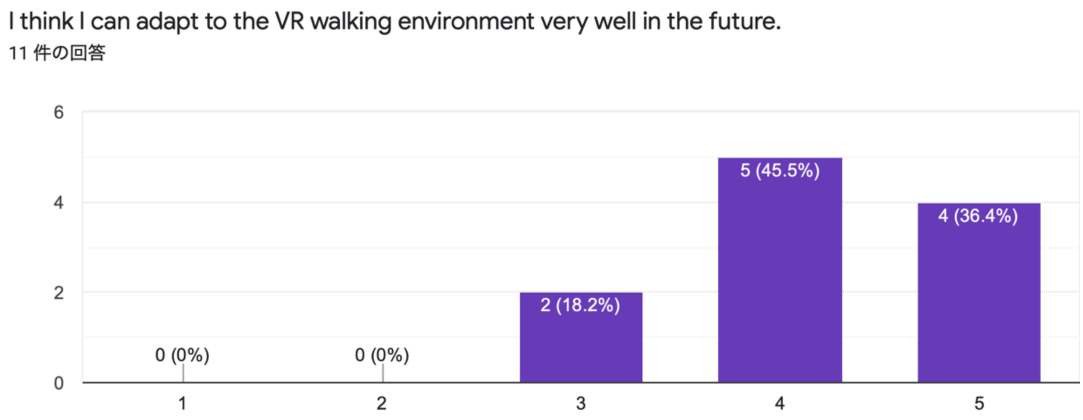

Figure 6.18 Future implications

After using this system, the user's assessment of his or her ability to adjust to a more natural VR walking environment is shown in Figure 6.7. This can reveal whether the users concur that the method is effective. Users are prepared to encounter various VR walking situations in the future, with 45.5 % agreeing and 36.4 % strongly agreeing.

Table 6.3 Average score of the qusetionnaire

Question	Average Score
1. I like the VR environment of the adaptive training system.	4.55
2. I thought this system was easy to operate.	4.36
3. I can feel the difference in the VR navigation speed.	4.73
4. I thought this system did help me reduce the VR sickness symptoms.	4.27
5. I enjoyed this experience a lot.	4.27
6. My interest in VR has increased after this experience.	4.27
7. I think I can adapt to the VR walking environment very well in the future.	4.18

This questionnaire is a 5-Point Likert Scale, the validity of the system can be judged by the average of the results in Table 6.3. The system can indeed match the needs, as evidenced by the fact that the mean score across all questions is higher than 4.

Question 1,2,3 was asked about the functionality of this system, reflecting the aesthetics and operability of this system and demonstrating the effectiveness of the primary speed change feature. Question 4 addresses the main objective of this system by asking whether the user can feel that their VR sickness symptoms are reduced. This system would reduce the user's fear of VR due to VR sickness and increases the user's interest in VR. Question 6 shows that all the subjects' interest in VR increased after experiencing the system. Question 7 shows that the users are confident that they can adapt to different VR environments in the future, which proves that the system can help reduce the user's fear of VR due to VR sickness and increases the user's interest in VR, which can promote the development of VR industry.

7 CONCLUSION AND FUTURE WORK

7.1 Summary

This research presents a novel approach to the problem of virtual reality (VR) sickness symptoms, which consists of assisting users in adjusting to VR sickness symptoms brought on by navigation speed through the use of adaptive training. In addition to this, an adaptive training method for the symptoms of VR sickness was established.

There is a correlation between the speed of navigation in virtual reality environments and the development of symptoms of sickness caused by VR. The user has the ability to alter and determine the speed of the navigation in this system. Users of this system have the ability to control the speed of the navigation and to move about freely in the virtual reality environment. Build up user's tolerance to the virtual reality environment in a short time by becoming adaptedto moving around in it.

The results of the experiment and the evaluation of user evaluation both lead us to the conclusion that this technology is actually capable of assisting users in alleviating the sickness-inducing effects of VR. The majority of users' enthusiasm for virtual reality (VR) has grown as a result of their participation in this adaptive training method. At the same time, more than eighty percent of consumers have the opinion that they are confident in their ability to adapt to various virtual reality walking situations.

This demonstrates that users of this device do experience some relief from the symptoms of VR as a result of using it. It has the potential to assist users in becoming more adaptedto the VR environment. Can increase the size of the virtual reality market and help advance the technology of virtual reality by lowering the percentage of potential VR users who avoid the technology out of fear of experiencing sickness when using VR.

7.2 Limitation and Future Work

It has been established by studies that are pertinent. The user may experience sickness as a result of the movement of the virtual reality (VR) environment due to the movement speed, the rotation pattern, and the shock magnitude. On the other hand, the only adaptation training that was done for the sickness that was caused by the movement speed in this study. As a result, adaption training for rotation mode and shock amplitude is going to be absolutely necessary in the future. If it is possible to combine such characteristics to assist users adapt to the VR sickness symptoms created by these three factors in a short amount of time, then it may be possible for users to better adapt to moving around in the virtual reality environment.

In addition, during the experiment of virtual reality (VR) adaptation training for sickness, several of the subjects indicated that the process was excruciating. This is due to the fact that at the conclusion of the event, each participant in the experiment was assessed for their level of subjective sickness symptoms. When predicting that users may experience VR sickness, the current adaptive training is stopped in time and restarted after adjustment if it can be combined with the study of VR sickness symptoms and prediction. This is done by judging the changes in users' physiological indicators. If this can be done, the study of VR sickness symptoms and prediction can be combined. It is possible that this will significantly improve the user's experience and make the process of adaption training more fun for the user.

In addition, throughout the experiment, the vast majority of the test subjects reported that they would not experience severe VR sickness symptoms when moving around in the virtual reality environment of this system and maintaining their position on the road. On the other hand, users reported experiencing severe sickness while using virtual reality headsets when they were disoriented, approached buildings, or crashed into buildings owing to incorrect functioning. Therefore, it is possible to draw the conclusion that the distance between the user and the reference item may be associated to VR sickness when the user is moving around in a virtual reality environment.

if VR sickness can someday be eliminated as a concern. Virtual reality is fun for everyone. The virtual reality (VR) industry will grow quickly, as will the size of the market. As a result, virtual reality will be applied more frequently in a variety of industries and to everyday life. The metaverse will be able to grow quickly at the same time as people's lives could alter drastically and human culture could advance to a new level.

ACKNOWLEDGEMENT

I want to start by expressing my sincere gratitude to Professor Ogi. The completion of this thesis was guided by Professor Ogi. I experienced a lot of confusion and difficulties throughout the course of my research and constantly get a lot of advise and recommendations from Professor Ogi. I couldn't have completed my research without Professor Ogi's help.

I also wish to thank Professor Ioki for his many insightful comments and thesis-related suggestions. His kind remarks were as a source of comfort and inspiration for me while I toiled away to finish my thesis.

I also want to express my gratitude to everyone who took part in my experiment. I want to thank you everyone for coming and supporting my study. Throughout the experiment, every participant had gone through the terrible symptoms of VR sickness. But they continue to assist me in completing the experiment. Without your assistance, there is no way that I can do it.

Last but not least, I want to thank all the professors and faculty members of Keio SDM. The classes I took over the past two years taught me a lot. All the knowledge I got from SDM not only helped me finish this my research, but also would help me in the rest of that my life. I also like to thank the SDM student I once met and worked with. It can be very challenging to adjust to a new environment as an international student. But every student I've met at SDM has treated me with kindness. They greatly helped me.

REFERENCE

[1] LaViola, J. J. (2000). A discussion of cybersickness in virtual environments. ACM SIGCHI Bulletin, 32(1), 47–56. https://doi.org/10.1145/333329.333344

[2] Alsop, T. (2022, March 4). *Virtual reality (VR) - statistics & facts*. Statista. https://www.statista.com/topics/2532/virtual-reality-vr/#dossierKeyfigures

[3] Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual Reality Sickness: A Review of Causes and Measurements. *International Journal of Human–Computer Interaction*, *36*(17), 1658–1682. https://doi.org/10.1080/10447318.2020.1778351

[4] Keshavarz, B., Hecht, H., & Zschutschke, L. (2011). Intra-visual conflict in visually induced motion sickness. *Displays*, *32*(4), 181–188. https://doi.org/10.1016/j.displa.2011.05.009

[5] Kim, Y. Y., Kim, E. N., Park, M. J., Park, K. S., Ko, H. D., & Kim, H. T. (2008). The Application of Biosignal Feedback for Reducing Cybersickness from Exposure to a Virtual Environment. *Presence: Teleoperators and Virtual Environments*, *17*(1), 1–16. https://doi.org/10.1162/pres.17.1.1

[6] 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. https://doi.org/10.1207/s15327108ijap0303_3

[7] Keshavarz, B., & Hecht, H. (2011). Axis Rotation and Visually Induced Motion Sickness: The Role of Combined Roll, Pitch, and Yaw Motion. *Aviation, Space, and Environmental Medicine*, *82*(11), 1023–1029. https://doi.org/10.3357/asem.3078.2011

[8] Bos, J. E., de Vries, S. C., van Emmerik, M. L., & Groen, E. L. (2010). The effect of internal and external fields of view on visually induced motion sickness. *Applied Ergonomics*, *41*(4), 516–521. https://doi.org/10.1016/j.apergo.2009.11.007

[9] VanSickle, M., Tucker, J., Daruwala, S., & Ghahramanlou-Holloway, M. (2016). Development and psychometric evaluation of the Military Suicide Attitudes Questionnaire (MSAQ). *Journal of Affective Disorders*, *203*, 158–165. https://doi.org/10.1016/j.jad.2016.03.065

[10] Hill, K., & Howarth, P. (2000). Habituation to the side effects of immersion in a virtual environment. *Displays*, *21*(1), 25–30. https://doi.org/10.1016/s0141-9382(00)00029-9

[11] Sugita, N., Yoshizawa, M., Abe, M., Tanaka, A., Watanabe, T., Chiba, S., Yambe, T., & Nitta, S. I. (2007). Evaluation of adaptation to visually induced motion sickness based on the maximum cross-correlation between pulse transmission time and heart rate. *Journal of NeuroEngineering and Rehabilitation*, *4*(1). https://doi.org/10.1186/1743-0003-4-35

[12] So, R. H. Y., Lo, W. T., & Ho, A. T. K. (2001). Effects of Navigation Speed on Motion Sickness Caused by an Immersive Virtual Environment. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *43*(3), 452–461. https://doi.org/10.1518/001872001775898223

[13] Stanney, K. M., Kennedy, R. S., & Hale, K. S. (2014). Virtual environment usage protocols. In K. S. Hale & K. M. Stanney (Eds.), *Handbook of virtual environments: Design, implementation, and applications* (2nd ed., pp. 797–809).

[14] J. Hakkinen, T. Vuori and M. Paakka, "Postural stability and sickness symptoms after HMD use," IEEE International Conference on Systems, Man and Cybernetics, 2002, pp. 147-152, doi: 10.1109/ICSMC.2002.1167964.

[15] Freitag, S., Weyers, B., & Kuhlen, T. W. (2016). Examining Rotation Gain in CAVE-like Virtual Environments. *IEEE Transactions on Visualization and Computer Graphics*, *22*(4), 1462–1471. https://doi.org/10.1109/tvcg.2016.2518298

[16] Häkkinen, J., Vuori, T., & Puhakka, M. (2002). Postural stability and sickness symptoms after HMD use. Proceedings of the IEEE International Conference on

Systems, Man and Cybernetics, 1, 147–152. https://doi.org/10.1109/icsmc.2002.1167964

[17] Jaeger, B. K., & Mourant, R. R. (2001). Comparison of simulator sickness using static and dynamic walking simulators. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 45(27), 1896–1900. https://doi.org/10.1177/154193120104502709

[18] Benzeroual, K., & Allison, R. S. (2013). Cyber (motion) sickness in active stereoscopic 3D gaming. Proceedings of the 2013 International Conference on 3D Imaging (IC3D), 1–7. https://doi.org/10.1109/ic3d.2013.6732090

[19] Llorach, G., Evans, A., & Blat, J. (2014). Simulator sickness and presence using HMDs: Comparing use of a game controller and a position estimation system. Proceedings of the 20th ACM Symposium on Virtual Reality Software and Technology, 137–140. https://doi.org/10.1145/2671015.2671120

[20] Rebenitsch, L., & Owen, C. (2016). Review on cybersickness in applications and visual displays. Virtual Reality, 20(2), 101–125. https://doi.org/10.1007/s10055-016-0285-9

[21] Bronstein, A. M., Golding, J. F., & Gresty, M. A. (2020). Visual Sickness, Motion Sickness, and Disorientation in Vehicles. Seminars in Neurology, 40(1), 116–129. https://doi.org/10.1055/s-0040-1701653

[22] Kolasinski, E. M. (1995). Simulator sickness in virtual environments (Report No. ARI Technical Report 1027). U.S. Army Research Institute for the Behavioral and Social Sciences. https://apps.dtic.mil/docs/citations/ADA295861

[23] Renkewitz, H., & Alexander, T. (2007). Perceptual issues of augmented and virtual environments (Report No. ADA474154). Research Institute for Communication Information Processing, and Ergonomics (FKIE).

https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/ADA474154.xhtml#

[24] Bonato, F., Bubka, A., Palmisano, S., Phillip, D., & Moreno, G. (2008). Vection change exacerbates simulator sickness in virtual environments. Presence: Teleoperators and Virtual Environments, 17(3), 283–292. https://doi.org/10.1162/pres.17.3.283

[25] Davis, S., Nesbitt, K., & Nalivaiko, E. (2015). Comparing the onset of cybersickness using the Oculus Rift and two virtual roller coasters. Proceedings of the 11th Australasian Conference on Interactive Entertainment (IE 2015), 3–14. http://hdl.handle.net/1959.13/1324888

[26] Liu, C.-L., & Uang, S.-T. (2012). A study of sickness induced within a 3D virtual store and combated with fuzzy control in the elderly. Proceedings of the 2012 9th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), 334–338. https://doi.org/10.1109/FSKD.2012.6234149

[27] Fernandes, A. S., & Feiner, S. K. (2016). Combating VR sickness through subtle dynamic field-of-view modification. Proceedings of the 2016 IEEE Symposium on 3D User Interfaces (3DUI), 201–210. https://doi.org/10.1109/3DUI.2016.7460053

[28] Kobayashi, N., Iinuma, R., Suzuki, Y., Shimada, T., & Ishikawa, M. (2015). Using bio-signals to evaluate multi discomfort in image viewing-balancing visually induced motion sickness and field of view. Proceedings of the 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 6198–6201. https://doi.org/10.1109/EMBC.2015.7319808

[29] Stanney, K. M., Hale, K. S., Nahmens, I., & Kennedy, R. S. (2003). What to expect from immersive virtual environment exposure: Influences of gender, body

mass index, and past experience. Human Factors, 45(3), 504–520. https://doi.org/10.1518/hfes.45.3.504.27254

[30] Chen, Y.-C., Dong, X., Hagstrom, J., & Stoffregen, T. A. (2011). Control of a virtual ambulation influences body movement and motion sickness. Proceedings of the BIO Web of Conferences, 1, 1–3. https://doi.org/10.1051/bioconf/20110100016

[31] Bos, J. E., Bles, W., & Groen, E. L. (2008). A theory on visually induced motion sickness. Displays, 29(2), 47–57. https://doi.org/10.1016/j.displa.2007.09.002

[32] McCauley, M. E., & Sharkey, T. J. (1992). Cybersickness: Perception of self-motion in virtual environments. Presence: Teleoperators and Virtual Environments, 1(3), 311–318. https://doi.org/10.1162/pres.1992.1.3.311

[33] Duh, H. B.-L., Parker, D. E., & Furness, T. A. (2004). An independent visual background reduced simulator sickness in a driving simulator. Presence: Teleoperators and Virtual Environments, 13(5), 578–588. https://doi.org/10.1162/1054746042545283

[34] Häkkinen, J., Vuori, T., & Puhakka, M. (2002). Postural stability and sickness symptoms after HMD use. Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, 1, 147–152. https://doi.org/10.1109/icsmc.2002.1167964

[35] Keshavarz, B., Hecht, H., & Zschutschke, L. (2011). Intra-visual conflict in visually induced motion sickness. Displays, 32(4), 181–188. https://doi.org/10.1016/j.displa.2011.05.009

[36] Sharples, S., Cobb, S., Moody, A., & Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, *29*(2), 58–69. https://doi.org/10.1016/j.displa.2007.09.005

[37] Stern, R. M., Hu, S., Vasey, M. W., & Koch, K. L. (1989). Adaptation to vection-induced symptoms of motion sickness. Aviation, Space, and Environmental Medicine, 60(6), 566–572.

[38] Bagshaw, M., & Stott, J. R. (1985). The desensitization of chronically motion sick aircrew in the Royal Air Force. Aviation, Space, and Environmental Medicine, 56(12), 1144–1151.

[39] Yardley, L. (1992). Motion sickness and perception: A reappraisal of the sensory conflict approach. *British Journal of Psychology*, *83*(4), 449–471. https://doi.org/10.1111/j.2044-8295.1992.tb02452.x

[40] Golding, J. F. (1998). Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. *Brain Research Bulletin*, *47*(5), 507–516. https://doi.org/10.1016/s0361-9230(98)00091-4

[41] Hoshikawa, S., Sumida, H., Murakami, T., & Tanahashi, S. (2020). Effects of the oscillation frequency components on visually induced motion sickness. *Proceedings of the International Display Workshops*, 554. https://doi.org/10.36463/idw.2020.0554

[42] Regan, C. (1995). An investigation into nausea and other side-effects of head-coupled immersive virtual reality. *Virtual Reality*, *1*(1), 17–31. https://doi.org/10.1007/bf02009710

[43] A. S. Fernandes and S. K. Feiner, "Combating VR sickness through subtle dynamic field-of-view modification," 2016 IEEE Symposium on 3D User Interfaces (3DUI), 2016, pp. 201-210, doi: 10.1109/3DUI.2016.7460053.

[44] W. Kim, S. Lee and A. C. Bovik, "VR Sickness Versus VR Presence: A Statistical Prediction Model," in IEEE Transactions on Image Processing, vol. 30, pp. 559-571, 2021, doi: 10.1109/TIP.2020.3036782.

[45] H. Buhler, S. Misztal and J. Schild, "Reducing VR Sickness Through Peripheral Visual Effects," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2018, pp. 517-9, doi: 10.1109/VR.2018.8446346.

[46] Geršak, G., Lu, H. & Guna, J. Effect of VR technology matureness on VR sickness. Multimed Tools Appl 79, 14491–14507 (2020). https://doi.org/10.1007/s11042-018-6969-2

[47] Somrak, A., Humar, I., Hossain, M. S., Alhamid, M. F., Hossain, M. A., & Guna, J. (2019). Estimating VR Sickness and user experience using different HMD technologies: An evaluation study. *Future Generation Computer Systems*, *94*, 302–316. https://doi.org/10.1016/j.future.2018.11.041

[48] Keshavarz, B., Riecke, B. E., Hettinger, L. J., & Campos, J. L. (2015). Vection and visually induced motion sickness: how are they related? *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.00472

[49] Biocca, F. (1992). Will Simulation Sickness Slow Down the Diffusion of Virtual Environment Technology? *Presence: Teleoperators and Virtual Environments*, *1*(3), 334–343. https://doi.org/10.1162/pres.1992.1.3.334

[50] Çakir, A. (2015). Handbook of virtual environments: design, implementation, and applications, second edition, edited by Kelly S. Hale and Kay M. Stanney, CRC Press, 2014. *Behaviour & Information Technology*, *34*(7), 752–754. https://doi.org/10.1080/0144929x.2015.1013791

[51] Ruddle, R. (2004). Virtual and Adaptive Environments: Applications, Implications, and Human Performance Issues. *Presence: Teleoperators and Virtual Environments*, *13*(4), 506. https://doi.org/10.1162/1054746041944821

[52] Rebenitsch, L., & Owen, C. (2016). Review on cybersickness in applications and visual displays. *Virtual Reality*, *20*(2), 101–125. https://doi.org/10.1007/s10055-016-0285-9

[53] Wang, G., & Suh, A. (2019). User adaptation to cybersickness in virtual reality: A qualitative study. In Proceedings of the 27th European Conference on

Information Systems (ECIS) (European Conference on Information Systems - Information Systems for a Sharing Society, ECIS). Association for Information Systems (AIS). https://aisel.aisnet.org/ecis2019_rp/191/

[54] Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and Cybersickness in Virtual Reality Are Negatively Related: A Review. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00158

[55] Anglin, J. M., Sugiyama, T., & Liew, S. L. (2017). Visuomotor adaptation in head-mounted virtual reality versus conventional training. *Scientific Reports*, *7*(1). https://doi.org/10.1038/srep45469

[56] Regan, E. (1995). Some evidence of adaptation to immersion in virtual reality. *Displays*, *16*(3), 135–139. https://doi.org/10.1016/0141-9382(96)81213-3

[57] J. Plouzeau, J. Chardonnet and F. Merienne, "Using Cybersickness Indicators to Adapt Navigation in Virtual Reality: A Pre-Study," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2018, pp. 661-662, doi: 10.1109/VR.2018.8446192.

[58] K. K. K. Kwok, A. K. T. Ng and H. Y. K. Lau, "Effect of Navigation Speed and VR Devices on Cybersickness," 2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), 2018, pp. 91-92, doi: 10.1109/ISMAR-Adjunct.2018.00041.

[59] J. E. Bos, S. N. MacKinnon and A. Patterson, "Motion sickness symptoms in a ship motion simulator: effects of inside outside and no view", Aviation Space and Environmental Medicine, vol. 76, no. 12, pp. 1111-1118, dec 2005.

[60] K. Kim, M. Z. Rosenthal, D. J. Zielinski and R. Brady, "Effects of virtual environment platforms on emotional responses", Computer Methods and Programs in Biomedicine, vol. 113, no. 3, pp. 882-893, mar 2014.

APPENDIX

Evaluation of VR Sickness Training System

1. Gender

□ Male

□ Female

□ Prefer not to say

2. Age

□ ~ 20

□ 21~30

□ 31~40

□ 41~50

□ 51~60

□ 60~

3. Do you have interest in VR

□ Yes

□ No

□ Maybe

4. How often do you use VR

☐ Never

☐ Rarely

☐ Occasionally

☐ Frequently

☐ Very frequently

5. I like the VR environment of the adaptive training system.

☐ Strongly disagree

☐ Disagree

☐ Undecided

☐ Agree

☐ Strongly agree

6. I thought this system was easy to operate.

☐ Strongly disagree

☐ Disagree

☐ Undecided

☐ Agree

☐ Strongly agree

7. I can feel the difference in the VR navigation speed.

□ Strongly disagree

□ Disagree

□ Undecided

□ Agree

□ Strongly agree

8. I thought this system did help me reduce the VR sickness symptoms.

□ Strongly disagree

□ Disagree

□ Undecided

□ Agree

□ Strongly agree

9. I enjoyed this experience a lot.

□ Strongly disagree

□ Disagree

□ Undecided

□ Agree

□ Strongly agree

10.My interest in VR has increased after this experience.

□ Strongly disagree

□ Disagree

□ Undecided

□ Agree

□ Strongly agree

11.I think I can adapt to the VR walking environment very well in the future.

□ Strongly disagree

□ Disagree

□ Undecided

□ Agree

□ Strongly agree