Understanding the Cybersickness Effects of Using Virtual Reality-based Classrooms for Undergraduate Students: A Preliminary Study

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Abstract

Purpose – Virtual reality (VR) technologies have expanded their domain of application towards education, offering various pedagogical advantages such as an immersive environment, teaching innovation, and in-depth user engagement by allowing the students to experience real-life scenarios of the taught subject through virtual simulations. Motion sickness, as one of the long-standing key challenges of VR utilization, even in gaming, often becomes a barrier for VR users to fully engage with the content developed in the virtual world. Thus, this work presents a preliminary study on understanding the symptoms of motion sickness — which will be referred to later as 'cybersickness' — in the teaching and learning (T&L) context.

Design/methodology/approach – A VR-based virtual classroom (V-Room) was developed and tested, in which 60 undergraduate students at the University of Nottingham Ningbo China (UNNC) participated. In this study, the students were equipped with the same VR headset and had the same V-Room environment. Data were collected through a two-step questionnaire, using both qualitative and quantitative measures, that was distributed to the participants before and after the study session. The severity of cybersickness was categorized into low-impact, medium-impact, and high-impact symptoms, alongside an overall comfort level experienced in the V-Room. Using the ANOVA F-test statistical approach, the data were analysed based on the following two research questions: (1) Has gender an influence on the presence of cybersickness symptoms?; and (ii) Does students' academic background (i.e. natural sciences and social science) also affect their experience in using VR for learning?

Findings – The results demonstrated that approximately 47% of the participants had experienced cybersickness during the V-Room experiential journey, of whom 64% were females. With a confidence level of 95% (α=5%), the p-value obtained for the respective gender and study discipline categories against the cybersickness symptoms were all smaller than 0.05, indicating that there was a significant difference between the two compared variables. Likewise, the F-statistical value was larger than the F-critical value, showing that both gender and study discipline have a considerable impact on the cybersickness. Moreover, it is worth highlighting that the top three factors that caused the cybersickness were the speed of the virtual movement, the perspective angle, and the visual properties of the virtual environment.

Originality/value/implications – It is hoped that the results of this study provide valuable pointers for future VR-based virtual classroom developers to minimize the cybersickness symptoms in the higher education T&L context that would enable an effective learning environment for the students.

Keywords: V-Room, virtual reality, cybersickness, motion sickness, teaching and learning, education technology

1 Introduction

Motion sickness (MS) is a common syndrome that typically occurs due to the mismatch between perceived and expected motion (Takov & Tadi, 2021). Nooij et al. (2021) believed that MS could also be induced by the belief that motion is happening, although in reality, no motion is detected. MS usually manifests differently on different individuals, although many reported overlapping symptoms such as nausea, headache, stomach awareness, disorientation, vomiting and more (Golding, 2016; Takov & Tadi, 2021). According to Lackner (2014), MS can be instigated by three types of motion: physical, visual, and virtual.

In recent years, visual and virtual motion sickness (collectively designated as visually induced motion sickness or VIMS) are increasingly reported along with the rapid development of visual and virtual technologies, such as the 3D motion picture in cinemas (Flanagan et al., 2004; Solimini, 2013) and virtual reality (VR) technologies (Chang et al., 2020).

Following the rising use of VR technologies in daily life and the emergence of affordable low-cost VR equipment, VR cybersickness continues to be one of the most common side effects of using VR. There is thus an increasing need to better understand the effects and impacts of motion sickness in VR. Thus, it is important to first understand the relationship of different factors that potentially cause or trigger the occurrence VR cybersickness.

1.1 Motion Sickness

Virtual Reality motion sickness (VRMS), also known as cybersickness or virtual reality sickness, is a subset of MS that is often linked to the use or immersion in VR environments (Chang et al., 2020; Yildirim, 2019). People who experienced VRMS typically reported similar symptoms compared to that of traditional MS (Chang et al., 2020; McCauley & Sharkey, 1992; Yildirim, 2019).

One notable study by Mazloumi Gavgani et al. (2018) has tried to compare between VRMS and "classical" MS. The study had concluded that "cybersickness and classic motion sickness are clinically identical, at least in their advanced stages" (Gavgani et al., 2018, p.1679) based on the similarity of symptoms and autonomic changes between VRMS and traditional MS in the same group of volunteer participants.

The occurrence of VRMS could be explained through the sensory conflict theory, i.e., the mismatch between visual stimuli and the vestibular senses (Ng et al., 2020). When VR users are immersed in virtual environments, what they observe are created

virtually and usually do not correspond to their physical situation or position, thus causing different feedbacks between what the eyes see and what they experienced physiologically.

1.2 VR Cybersickness (VRC) in Various Applications

As VR technologies are being continuously developed and studied, its application amongst a plethora of discipline has also increased, especially in the field of higher education, video games, medicine/healthcare, and the social sciences, such as history (Cipresso et al., 2018; Radianti et al., 2020; Yildirim, 2019).

In the context of VRC presence in the field of healthcare, Servotte et al. (2020) conducted a study specifically amongst a group of predominantly undergraduate healthcare students and postgraduates with no special trainings. The study used a specially made VR simulation that was developed following medical emergencies scenarios that were designed by healthcare professionals. Servotte et al. found that a high sense of presence during VR immersion is associated with low level of cybersickness, albeit discomfort caused by VR was still observed. To add on, a study by Taylor & Layland (2019) tried to investigate different forms of virtual simulations and its prevalence in inducing VRC in the context of healthcare. Amongst the simulations were "360-degree video, manikin, standardised patient, and video case study" (Taylor & Layland, 2019, p.171). It was found that participants are not more likely to get MS from VR-based simulation than from other type of simulations, thus justifying the use of VR in healthcare.

The presence of VRC in video games, another field involves VR technologies and VRC, has also been widely investigated. Most video games incorporate elements of digital graphics, storytelling, and user immersion to deliver a compelling narrative and gameplay that draw players to play it. VR video games, which offer fully-immersive virtual environments, are of no exception to cause cybersickness. However, Weech et al. (2020) has interestingly found that VRC is negatively correlated to the sense of presence in VR games. To put it simply, an enriched narrative/story allows for players to be more immersed and present in the game, which in turn reduces the effect of cybersickness.

Having looked at how common the MS and VRC symptoms appeared in the use of digital to virtual environment in various applications, the current work focuses on a specific implementation in the context of Higher Education to observe students reaction towards this, *i.e.,* when a VR-based classroom is used in their teaching and learning conduct. Hence, a pilot study was conducted to investigate whether the cybersickness effects are linked to the utilisation of VR devices, and if so, the symptoms that are associated with the VRC will also be identified. In this paper, the presence of VRC symptoms in the use of a VR-based classroom, and how these symptoms are related to the students' background will be identified. Causes of the VRC symptoms, when present, will also be studied according to the students' receptive level of severity and commonness during the VR experience of the virtual classroom. The following sections will present and analyse the data obtained from the pilot study survey, starting from how the study was designed and conducted (Section

2), statistical process of the survey data analysis (Section 3), and what can be concluded from the results including future work of this study (Section 4).

2 Methodologies

This V-Room pilot study aims to provide a preliminary understanding of the VRC effect of using VR-based classroom in the teaching and learning area for undergraduate students. The study has been reviewed and approved by the University Research Ethics Subcommittee according to the ethical review processes of UNNC. These processes, as shown in Figure 1, are governed by the University's Code of Research Conduct and Research Ethics.

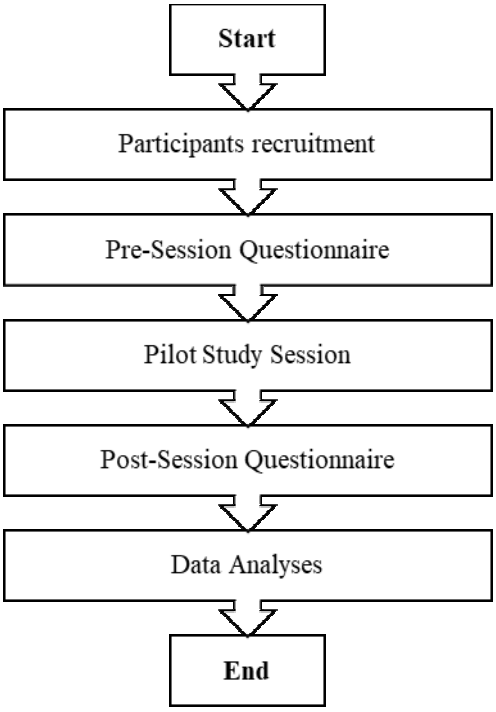

Fig. 1. Flowchart of the V-Room research methodology

2.1 Participants

A total of 60 healthy participants from various study disciplines were selected to participate in the study following a volunteer sampling method. Amongst these participants, 33 came from study disciplines of the Social Sciences, and 27 from the Natural Sciences. Table 1 below summarises the demography of the participants based on their gender and study disciplines. It was worthwhile noting that from this

pool of participants, 68.3% of the participants have had previous experience with the use of VR technologies and equipment.

Table 1. Participants Demography (Disciplines & Gender)

Study Disciplines	Male	Female	Total *n*
Natural Sciences	14	13	**27**
Social Sciences	13	20	**33**
Total *n*	**27**	**33**	**60**

Each participant was informed that their participation in the study was entirely voluntary and that they were able to withdraw from the study at any time. Information regarding each participant were kept confidential in accordance with the data storage requirements outlined in the University's Code of Research Conduct.

2.2 Questionnaire

Prior to the start of the study, a pre-session questionnaire has been sent to the registered participants to collect information about their prior VR experience and knowledge, including if they have ever used VR equipment and experienced motion sickness in the past.

After the pilot study session, participants were asked to fill out a post-session questionnaire to obtain information about their VR experience and if they developed any MS symptoms. Based on the responses, participants who experienced VRC were then asked to rate the severity of their symptoms on a scale from 0 to 5, where 0 means the particular symptom did not manifest and 5 means the symptom was very severe. Additionally, the participants were also asked to identify the possible factor that may have induced the VRC.

2.3 Pilot Study Design

Participants who volunteered to participate in the study was asked to select a predefined date and time slots to attend the V-Room pilot study. The pilot study spanned over the course of three weeks with two sessions allocated for each week, subject to the availability of the V-Room team personnel and participants. Prior to the study, the pre-session registration questionnaire was disseminated to the volunteers via an email message alongside the time booking slots.

The pilot study sessions were all conducted in the same controlled environment and approximately same environmental conditions to minimise data discrepancy between sessions. During the study sessions, participants were equipped with a mobile VR headset and audio listening device. A mobile phone with the V-Room application installed was provided for each mobile VR headset. The relevant specifications for each mobile phone used is outlined in Table 2.

Before the start of each session, participants were required to attend a briefing about the aims of the study, usage of the devices to be equipped, and health and safety advisory. When the participants were ready to undergo the V-Room experience, as shown in Figure 2, the team personnel assisted in equipping the VR headsets. Participants were also made aware of the possibility of VRC, which is a common

occurrence that many people experienced during the use of VR equipment. Participants who developed unbearable reactions towards VRC during the session were allowed to either stop the V-Room experiential journey or resume the study after a short rest period.

Table 2**.** Mobile Phone Specifications Outline

Specification	Device A	Device B	Device C
Screen Display			
Type	AMOLED, 120 Hz	IPS LCD, 60 Hz	IPS LCD, 120 Hz
Size	6.9"	6.3"	6.67"
Resolution	1440 x 3088 pixels (~496 ppi density)	1080 x 2340 pixels (~409 ppi density)	1080 x 2400 pixels (~395 ppi density)
Platform			
Operating System	Android 10	Android 10	Android 10
Chipset	Qualcomm SM8250 Snapgradon 865+ (7 nm+)	Qualcomm SDM675 Snapdragon 675 (11 nm)	Mediatek MT6889Z Dimensity 1000+ (7 nm)
CPU	Octa-core (1x3.0 GHz Kryo 585 & 3x2.42 GHz Kryo 585 & 4x1.8 GHz Kryo 585)	Octa-core (2x2.0 GHz Kryo 460 Gold & 6x1.7 GHz Kryo 460 Silver)	Octa-core (4x2.6 GHz Cortex-A77 & 4x2.0 GHz Cortex-A55)
GPU	Adreno 650	Adreno 612	Mali-G77 MC9

The V-Room experiential journey app provided participants with an objective-oriented exploration of three types of classroom designs, where each classroom has a unique feature that participants could try. Each of these rooms vary in terms of colour and interior designs, exposing participants to different aspects of visual design in a virtual environment.

This experiential journey provided each participant with a series of "objectives" that they needed to follow. Once an objective was cleared, they were then able to continue to the next objective. The objectives were designed such that participants were guided through all of the rooms to test the available features. VRC were expected from a portion of the participants, since several of the features and aspects of the VR environment were known to induce VRC, such as bright colours, sensory mismatch, and levitation.

Each session lasted, on average, about 10-12 minutes per participants or until the participant decided to end the session due to VRC. The participants were then allowed

to rest before asking them to fill the post-study questionnaire. V-Room team personnel were always present to assist the participants at any time during the pilot study session on a one-to-one ratio basis; that is one participant was supervised by one personnel.

Data from the questionnaires were then compiled and analysed by using the Analysis of Variance (ANOVA) F-test statistical analysis method whose results will be discussed in the following sections.

Fig. 2. Participant was equipped with the mobile VR headsets, courtesy of V-Room.

2.4 Statistical Method for Data Analyses

The ANOVA method was selected as the method to analyse the data that had been obtained from the study. The method was selected to investigate whether the two compared variables, *i.e.*, gender vs. VRC and study discipline vs. VRC, have statistical significance. The "significance" in the ANOVA test is hereby defined whether the variance between the two variables are significantly different from each other. In other words, the study investigates the influence of differences in gender and study discipline on the presence of VRC symptoms in the context of using a VR-based classroom for learning purpose.

This method uses two hypotheses, namely the null hypothesis (H_0) and the alternate hypothesis (H_1), to determine whether there is a statistically significance relationship between two variables (Larson, 2008; Pandis, 2015), *e.g.*, gender and VRC presence. Confidence level of 95% is used in this study, which means alpha (α) is 0.05. The results of an ANOVA would either be accepting or rejecting H_0. When H_0 is rejected, when p-value is smaller than the confidence level or when *F-statistic* value falls above F-critical (*F-crit*), it is said that there is a statistical significance in the data. If H_0 is accepted - thus rejecting the alternative hypothesis - it indicates that

there is not enough evidence in the data to justify that there exists a statistical significance in the compared sets of data.

For the ANOVA hypothesis test, five more variables need to be introduced for the purpose of results presentation in Section 3, as follows.

- *SS* denotes the 'Sum-of-Squares', a measure of variation from the mean value of a set of data, computed by summing over the squares of the deviations from the mean.
- *df* denotes the 'degrees of freedom'.
- *MS* denotes the 'Mean Squares', which is computed by dividing the sum-of-squares over the given degrees of freedom.
- *F-statistic value* is calculated by dividing an *MS* over another *MS* value.
- *P-value* is the probability value of observing and comparing *F*-statistic value, which is obtained from the study, with the value of *F*-critical, hence, to determine whether to reject or accept the null hypothesis.

3 Results and Analysis

3.1 Overview

Through the completion of the pre-session and post-session questionnaires, it was identified that almost 50% of the study participants (28 out of 60 students) experienced VRC of varying severity. Out of 28, 16 of them had used a VR headset and experienced VRC, mostly in games, prior to coming to the V-Room pilot study session. Background of the participants who experienced VRC during the V-Room experiential journey is provided Figure 3. Based on the study disciplines these participants came from, 15 and 13 participants were from the Social Sciences and Natural Sciences, respectively.

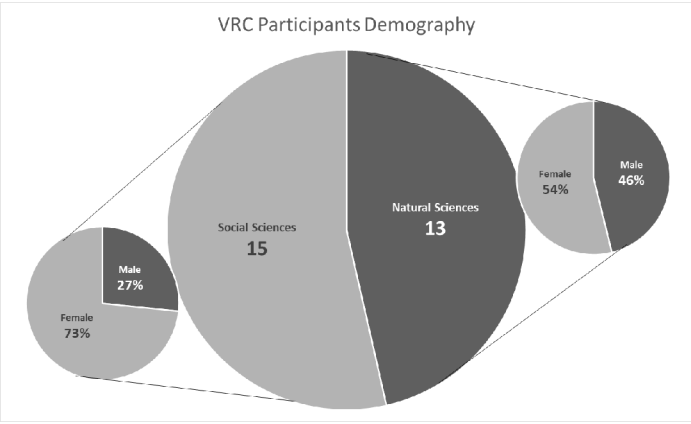

Fig. 3. Demography of the participants who experienced VRC during the V-Room study.

It could also be seen from Figure 3 that in both study disciplines, female participants were more susceptible to VRC than their male counterparts, *i.e.*, 73% females enrolled in the Social Sciences and 54% in the Natural Sciences. During the study, it was noted that all participants successfully completed the V-Room experiential journey session despite some having experienced VRC.

3.2 VRC Symptoms

The participants who experienced VRC during the pilot study were asked to rate their experience of each particular symptom on a scale of 0 to 5. Figure 4 illustrates the frequency of each symptom on participants. The graph also shows the distribution of each symptom on each gender. It is interesting to see that the most frequent VRC symptoms experienced by the participants were dizziness (25 participants) and discomfort (24 participants), followed by loss of balance and disorientation (19 participants, respectively). Meanwhile, the study also confirmed that female participants were at a higher risk in experiencing VRC than male participants.

Prior to analysing how significant demography of the participants affects the reaction towards VRC, the symptoms that were present were categorised based on the severity and commonness during a VRC experience. The results were then compared to one study conducted by Leung (2018), which provided an understanding on the pathophysiology and management of MS, as presented in Table 3. Symbol-coding was used to represent both the degree of severity and commonness and are explained in the legend below the table.

Based on the generated comparison, it could be seen that for most cases, the severities of the symptoms were similarly categorised, except in the cases of eye strain and sweating, which were respectively low-impact and medium impact in contrast to the medium-impact and high-impact that were described in the literature. Additionally, two of the symptoms that were observed in the study were not discussed in the literature and thus were not compared.

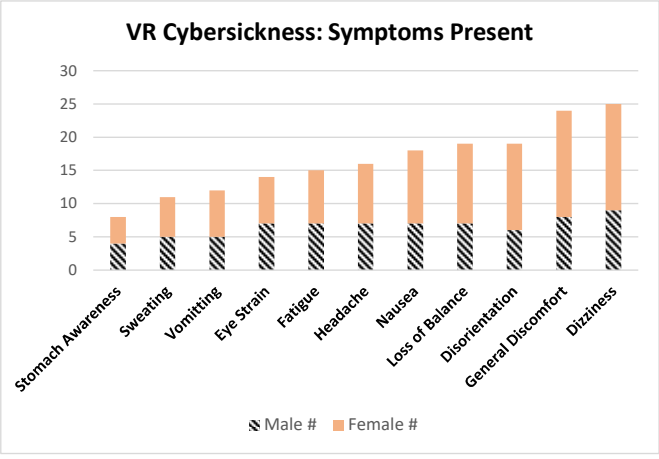

Fig. 4. VRC symptoms experienced by the V-Room study participants.

Table 3. Comparison of severity and commonness of VRC symptoms between literature data and data obtained in the study.

Symptoms	Literature*		Current Study: V-Room	
	Severity	*Commonness*	*Severity*	*Commonness***
General Discomfort	●	★★★★★	●	★★★★★
Fatigue	●	★★★★	●	★★★★
Nausea	■	★★★★★	■	★★★★
Eye Strain	■	★★★★★	●	★★★
Dizziness	■	★★★★★	■	★★★★★
Headache	▲	★★★★★	▲	★★★★
Disorientation	▲	★★★★	▲	★★★★
Sweating	▲	★★★	■	★★★
Vomiting	▲	★★★	▲	★★★
Loss of Balance	-***	-***	▲	★★★★
Stomach Awareness	-***	-***	■	★★

Legends for Severity:		Legends for Commonness:	
●	Low-Impact	★	Least Common
■	Medium-Impact	★★★★★	Most Common
▲	High-Impact		

Notes:
* The data from literature in the table are summarised from the literature.
** Commonness threshold was determined based on the number of participants who experienced VRC.
*** These symptoms were not present or described as a part of other symptoms in the literature.

Looking at the commonness aspect of the symptoms, there is a consensus between the literature and the study that general discomfort and dizziness are very common amongst people who experienced VRC. One notable symptom that differs greatly between the literature and the study was the eye strain, where in the study, participants reported only low-impact and it was not as commonly observed as the other symptoms. To summarise, the severity levels of the VRC symptoms used in this study analysis are categorised as follows.

i. Low-impact: fatigue, eye strain, and general discomfort.
ii. Medium-impact: sweating, nausea, dizziness, stomach awareness.
iii. High-impact: headache, loss of balance, disorientation, and vomiting.

3.3 VRC vs. Gender

To understand whether gender manifests a certain significance towards VRC in the context of utilising the developed VR-based classroom, a one-way ANOVA was used to analyse the data obtained from the study. For this, each of the VRC severity category was analysed against gender, *i.e.,* female and male, as shown in Table 4. The null hypothesis suggests that there is no evidence for gender and VRC symptoms to be statistically different.

The results showed that for all three categories, the *F-statistic* values are significantly higher than the *F-critical* values, respectively from low-impact to high-

impact: 38.927, 49.599, and 44.901 against 4.019, 4.019, and 4.019, which denotes that gender of the participants has a degree of significance when compared against VRC symptoms during the VR experience. In addition, this was further emphasised by the *p*-values, respectively 7.035E-08, 3.512E-09, and 1.26E-08, which are all below the value of α (0.05). This confirms the acceptance of an alternative hypothesis H_1 which states that there is a statistical significance between gender and the occurrence of VRC, therefore rejecting the null hypothesis H_0.

This finding is also supported by a study (Chattha & Shah, 2018) which has found that female participants have a greater chance of being afflicted by motion sickness while using VR. Another study by Chattha et al. (2020) further confirmed that gender is one of the statistically significant factors that plays a key role in the occurrence of VRC.

Table 4. One-way ANOVA of Gender vs. VRC symptoms with various severity levels: (i) low-impact; (ii) medium-impact; and (iii) high-impact.

Gender vs. Low-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	196.875	1	196.875	38.927	7.035E-08	4.019
Within Groups	273.107	54	5.058			
Total	469.982	55				

Gender vs. Medium-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	418.018	1	418.018	49.599	3.512E-09	4.019
Within Groups	455.107	54	8.428			
Total	873.125	55				

Gender vs. High-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	325.446	1	325.446	44.901	1.26E-08	4.019
Within Groups	391.393	54	7.248			
Total	716.839	55				

3.4 VRC vs. Study Disciplines

The relationship between study disciplines, divided into Natural Sciences and Social Sciences, and VRC symptoms is demonstrated in Table 5. The significance of these two sets of data is clearly demonstrated by having the *F*-statistic values (*i.e.,* 41.86, 52.16 and 47.53) larger than the *F*-critical value (*i.e.,* 4.02) for all VRC symptoms' severity levels, *i.e.*, low-impact, medium-impact, and high-impact. When calculating the total amount of Likert scale responses from the participants, it is also worth noticing that the medium-impact VRC received the largest responses from the study

participants, indicating the most common symptoms experienced by the participants; its value was higher by 10.5% and 28.1% than those of high-impact and low-impact VRC symptoms, respectively. To support these results, it is also evident that the obtained *p*-values were of infinitesimal numbers, very close to zero, and were much smaller than 0.05. These statistical findings led to the rejection of null hypothesis, meaning the two sets of data, study disciplines and VRC symptoms, differed significantly from each other.

Table 5. One-way ANOVA of Study Discipline vs. VRC symptoms with various severity levels: (i) low-impact; (ii) medium-impact; and (iii) high-impact.

Study Discipline vs. Low-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	212.161	1	212.161	41.8618	2.98088E-08	4.019541
Within Groups	273.679	54	5.068122			
Total	485.839	55				

Study Discipline vs. Medium-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	440.1607	1	440.1607	52.16106	1.79437E-09	4.019541
Within Groups	455.6786	54	8.438492			
Total	895.8393	55				

Study Discipline vs. High-impact VRC

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	345.0179	1	345.0179	47.5323	6.11562E-09	4.019541
Within Groups	391.9643	54	7.258598			
Total	736.9821	55				

3.5 Potential Causes of VRC

To further investigate potential causes of VRC, participants were asked to select the factors that they believed might have contributed to the occurrence of VRC. In this study, the factors that are being reviewed were the speed of movements, angle of movements, lag, graphics quality, and bright colours/lights.

Speed of Movements. In most VR experiences, player movements, also known as locomotion, is an important aspect because it provides a way for users to move around in the virtual environment. The types of locomotion may vary depending on the VR experience. The locomotion method that this study used was gaze-controlled walking.

Angle of Movements. Since the locomotion method in this study relied on the participants moving their head and eyes to gaze as the control, any movements that occurred would be accompanied by a change in the gaze angle. As noted by Gavgani et al. (2018), the action of tilting one's head does contribute to the possible manifestation of motion sickness.

Lag. Lag, or more formally known as Motion-to-Photon (MTP) latency, is one of the causes of motion sickness in most computer-related systems, including in VR (Stauffert et al., 2020). Lag in this study is defined as the delay between the participant's head movement and the virtual changes that correspond to the head movement.

Graphic Quality. Graphic quality generally refers to the visually significant aspects that are present in the VR environment. As Burningham et al. (2002) has noted, any image that is shown or produced on a display or printer could be evaluated in terms of quality by their viewers. Thus, this study asked participants to evaluate the graphic quality of the VR environment and whether it contributed to the manifestation of VRC.

Bright Colours/Lights. The use of bright colours or lights may also be a factor for VRC to occur. A study by Bonato et al. (2004) concluded that chromaticity may affect how stationary an environment is being perceived as and may be a contributing factor to motion sickness. In addition, another study by Vasylevska et al. (2019) have noted that the brightness of a head-mounted display (HMD) may also contribute to cybersickness, although inconclusive at the time and requires further investigation.

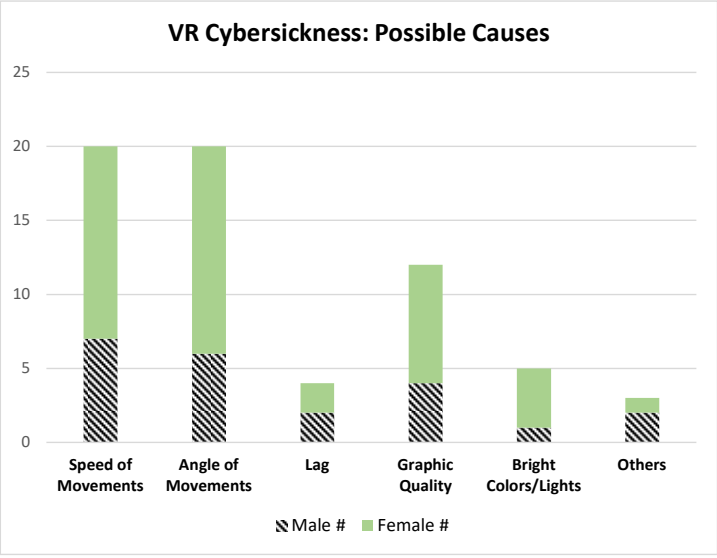

Fig. 5. Feedback from the participants regarding potential causes of VRC.

Table 6. Possible Causes of VRC and the Proportions of Male and Female Participants who Reported that Particular Cause.

Possible Causes	Male %	Female %
Speed of Movements	70%	72%
Angle of Movements	60%	78%
Lag	20%	11%
Graphic Quality	40%	44%
Bright Colours/Lights	10%	22%
Others	20%	6%

As reported by the participants in the study, the possible causes of VRC have been documented and illustrated in Figure 5 above, with 20 participants, each, reporting that speed of movements and angle of movements were a major cause of their VRC, followed by 12 participants who reported graphics quality, 5 reported graphics quality, and lag being the least likely to cause VRC with only 4 participants reporting it. Additionally, three other possible factors have been identified by three participants, namely: *"user control experience"; "levitation";* and *"*[use of] *mixed colours".*

In terms of the differences of possible causes of VRC amongst male and female, it was observed that a higher proportion of female participants believed that all of the factors, except lag, was the cause(s) of their VRC (shown in Table 6 above).

Some participants were asked about their use of the V-Room app and their experience of VRC during the study. One participant commented that "*the motion can be better*", while another agrees that "[sic] *the movement can be less dizzy*". When asked about what they believe could alleviate their VRC, one participant said, "[using] *high tech* [equipment] *to prevent sickness like [dizziness] and other uncomfortable symptom*", implying that a better hardware may be a key to reducing the occurrence of VRC.

4 Conclusion and Future Work

Pilot study conducted by the V-Room team focused on investigating the cybersickness effects of using a VR-based virtual classroom, has been completed. The aims are threefold:

i. Identification and qualitative analysis of the VRC symptoms;
ii. Statistical significance analysis of students' demography, *i.e.*, gender and study discipline, when compared against the occurrence of VRC symptoms;
iii. Understanding the potential causes that strongly contribute to VRC.

Responses received through the given questionnaire demonstrated that 46.7% participants, university UG students at UNNC, were affected by VRC symptoms when immersing themselves in the developed VR-based classroom. Based on the severity and commonness levels of VRC classification proposed in this study, medium-impact VRC received the highest number of responses from the study participants. This category includes sweating, nausea, dizziness, and stomach awareness. When assessed individually, out of 11 VRC symptoms considered, dizziness was the most frequent symptom experienced by the participants. It is also

worth mentioning that around 53.6% participants who experienced VRC came from the Social Sciences study discipline, a slightly higher percentage compared to participants with Natural Sciences background. In both cases, female participants were particularly found to be more prone to experiencing VRC.

One-way ANOVA results obtained from this study suggest that both gender and study disciplines offer statistical significances against the presence of VRC when a VR-based classroom is used by the university students in the T&L context. It is therefore worth considering the two factors, such as when developing a virtual environment for the students equipped with VR technologies.

Further investigation of the V-Room project would include the exploration of whether the presence of VRC influences the learning experience of these students, other factors that might correlate to VRC, and potential ways on minimising or reducing the effects of VRC on using a VR-based classroom. By understanding the preliminary results of the presence of VRC symptoms and potential causes of VRC from this study, especially in the Higher Education sector applications, it is hoped that the key findings can be used as a guideline for designing and developing an effective virtual learning environment.

References

Bonato, F., Bubka, A., & Alfieri, L. (2004). Display Color Affects Motion Sickness Symptoms in an Optokinetic Drum. Aviation Space and Environmental Medicine, 75(4 SEC. I), 306–311.

Burningham, N., Pizlo, Z., & Allebach, J. P. (2002). Image Quality Metrics. In Encyclopedia of Imaging Science and Technology. John Wiley & Sons, Inc. https://doi.org/10.1002/0471443395.img038.

Chattha, U. A., Janjua, U. I., Anwar, F., Madni, T. M., Cheema, M. F., & Janjua, S. I. (2020). Motion Sickness in Virtual Reality: An Empirical Evaluation. IEEE Access, 8, 130486–130499. https://doi.org/10.1109/ACCESS.2020.3007076.

Chattha, U. A., & Shah, M. A. (2018, September 1). Survey on causes of motion sickness in virtual reality. *ICAC 2018 - 2018 24th IEEE International Conference on Automation and Computing: Improving Productivity through Automation and Computing*. https://doi.org/10.23919/IConAC.2018.8749071.

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.

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*, *9*(NOV). https://doi.org/10.3389/fpsyg.2018.02086.

Flanagan, M. B., May, J. G., & Dobie, T. G. (2004). The role of vection, eye movements and postural instability in the etiology of motion sickness. *Journal of Vestibular Research*, *14*(4), 335–346.

Gavgani, A. M., Walker, F. R., Hodgson, D. M., & Nalivaiko, E. (2018). A comparative study of cybersickness during exposure to virtual reality and "classic" motion sickness: Are they different? *Journal of Applied Physiology*, *125*(6), 1670–1680. https://doi.org/10.1152/japplphysiol.00338.2018

Golding, J. F. (2016). Motion sickness. In *Handbook of Clinical Neurology* (Vol. 137, pp. 371–390). Elsevier B.V. https://doi.org/10.1016/B978-0-444-63437-5.00027-3.

Lackner, J. R. (2014). Motion sickness: More than nausea and vomiting. In *Experimental Brain Research* (Vol. 232, Issue 8, pp. 2493–2510). Springer Verlag. https://doi.org/10.1007/s00221-014-4008-8.

Larson, M. G. (2008). Analysis of variance. In *Circulation* (Vol. 117, Issue 1, pp. 115–121). Lippincott Williams & Wilkins. https://doi.org/10.1161/CIRCULATIONAHA.107.654335.

Leung, A., & Hon, K. (2019). Motion sickness: an overview. Drugs in Context, 8. https://doi.org/10.7573/dic.2019-9-4.

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.

Ng, A. K. T., Chan, L. K. Y., & Lau, H. Y. K. (2020). A study of cybersickness and sensory conflict theory using a motion-coupled virtual reality system. *Displays*, *61*, 101922. https://doi.org/10.1016/j.displa.2019.08.004.

Nooij, S. A. E., Bockisch, C. J., Bülthoff, H. H., & Straumann, D. (2021). Beyond sensory conflict: The role of beliefs and perception in motion sickness. *PLOS ONE*, *16*(1), e0245295. https://doi.org/10.1371/journal.pone.0245295.

Pandis, N. (2015). Analysis of variance. In *American Journal of Orthodontics and Dentofacial Orthopedics* (Vol. 148, Issue 5, pp. 868–869). Mosby Inc. https://doi.org/10.1016/j.ajodo.2015.08.009.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers and Education*, *147*, 103778. https://doi.org/10.1016/j.compedu.2019.103778.

Servotte, J. C., Goosse, M., Campbell, S. H., Dardenne, N., Pilote, B., Simoneau, I. L., Guillaume, M., Bragard, I., & Ghuysen, A. (2020). Virtual Reality Experience: Immersion, Sense of Presence, and Cybersickness. *Clinical Simulation in Nursing*, *38*, 35–43. https://doi.org/10.1016/j.ecns.2019.09.006.

Stauffert, J.-P., Niebling, F., & Latoschik, M. E. (2020). Latency and Cybersickness: Impact, Causes, and Measures. A Review. Frontiers in Virtual Reality, 1, 582204. https://doi.org/10.3389/frvir.2020.582204

Solimini, A. G. (2013). Are There Side Effects to Watching 3D Movies? A Prospective Crossover Observational Study on Visually Induced Motion Sickness. *PLoS ONE*, *8*(2). https://doi.org/10.1371/journal.pone.0056160.

Takov, V., & Tadi, P. (2021). Motion Sickness. In *StatPearls*. http://www.ncbi.nlm.nih.gov/pubmed/30969528.

Taylor, N., & Layland, A. (2019). Comparison study of the use of 360-degree video and non-360-degree video simulation and cybersickness symptoms in undergraduate healthcare curricula. *BMJ Simulation and Technology Enhanced Learning*, *5*(3), 170–173. https://doi.org/10.1136/bmjstel-2018-000356.

Vasylevska, K., Yoo, H., Akhavan, T., & Kaufmann, H. (2019). Towards eye-friendly VR: How bright should it be? 26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 - Proceedings, 566–574. https://doi.org/10.1109/VR.2019.8797752

Weech, S., Kenny, S., Lenizky, M., & Barnett-Cowan, M. (2020). Narrative and gaming experience interact to affect presence and cybersickness in virtual reality. *International Journal of Human Computer Studies*, *138*, 102398. https://doi.org/10.1016/j.ijhcs.2020.102398.

Yildirim, C. (2019). Cybersickness during VR gaming undermines game enjoyment: A mediation model. *Displays*, *59*, 35–43. https://doi.org/10.1016/j.displa.2019.07.002.