UNIVERSITY OF OULU
FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Tapio Kursula

The Association between the Perceived Cybersickness and Amount of Visual Detail in Virtual Environments

Bachelor's Thesis
Degree Programme in Computer Science and Engineering
May 2019

Kursula T. (2019) The Association between the Perceived Cybersickness and the Amount of Visual Detail in Virtual Environments. University of Oulu, Degree Programme in Computer Science and Engineering. Bachelor's Thesis, 25 p.

ABSTRACT

Cybersickness is a condition similar to motion sickness that can affect people who are immersed in a virtual reality. Cybersickness has been studied for multiple decades and a large part of its research base comes from older areas of motion sickness studies, such as simulator sickness studies. Questionnaires have been the main data gathering method in cybersickness studies, although recently opting for more objective measurement methods have been on the rise. The level of visual detail appears to correlate with the perceived cybersickness.

In this thesis, a data collection is done to compare two scenes has been done for later analysis. The scenes are otherwise identical, but different in amount of visual detail. The intention is to compare the scenes with each other to see if there is a difference in the cybersickness they cause. The subjects were shown a high-detail scene and a low-detail scene, one subject seeing both scenes. Cybersickness was assessed with questionnaires. Various sensor data were also collected and the point-of-view of the subject in the virtual scene was recorded.

Altogether 22 subjects participated in the study. The perceived level of cybersickness was slightly lower in scenes with lower amount of visual detail when compared to the more realistic scene. In particular, the realistic scene appeared to cause slightly more nausea than the simple scene. However, small sample size and the subjective nature of cybersickness lower the overall reliability of the results.

Keywords: cybersickness

Kursula T. (2019) The Association between the Perceived Cybersickness and the Amount of Visual Detail in Virtual Environments. University of Oulu, Degree Programme in Computer Science and Engineering. Bachelor’s Thesis, 25 p.

TIIVISTELMÄ

Virtuaalipahoinvointi (*cybersickness*) on liikepahoinvointia vastaava tila, joka voi ilmetä ihmisten ollessa uppoutuneena virtuaaliseen todellisuuteen. Virtuaalipahoinvointia on tutkittu useiden vuosikymmenten ajan, ja suuri osa virtuaalipahoinvoinnin tutkimuspohjasta on peräisin vanhemmista liikepahoinvointitutkimuksista, kuten simulaatiopahoinvointitutkimuksista. Kyselyt ovat olleen vakiintunut menetelmä virtuaalipahointivointitutkimuksessa, joskin objektiivisemmat menetelmät ovat alkaneet yleistyä. Visuaalisten yksityiskohtien määrä näyttäisi korreloivan koetun virtuaalipahoinvoinnin kanssa.

Tämä kandidaatin tutkielma sisältää aineiston keruun. Aineisto toimii pohjana myöhemmin toteutettavaan analyysiin, jonka tarkoituksena on verrata kahta virtuaalista näkymää, joiden ainoana erona on visuaalisten yksityiskohtien määrä. Tarkoituksena on verrata virtuaalipahoinvoinnin määrää näkymien välillä. Tutkimushenkilöille näytettiin realistinen näkymä ja yksinkertainen näkymä siten, että kullekin tutkimushenkilöllle näytettiin kumpikin näkymä kerran. Virtuaalipahoinvointia mitattiin kyselyillä. Lisäksi kerättiin sensoridataa sekä tutkimushenkilön katseen suunta virtuaalisessa ympäristössä.

Yhteensä 22 tutkimushenkilöä osallistuivat tutkimukseen. Koetun virtuaalipahoinvoinnin määrä oli hieman matalampi yksinkertaisen näkymän yhteydessä verrattuna realistiseen näkymään. Realistisempi näkymä vaikutti aiheuttavan enemmän huono-oloisuutta (*nausea*). Pieni otoskoko ja virtuaalipahoinvoinnin subjektiivinen luonne heikentävät kuitenkin tulosten luotettavuutta.

Keywords: virtuaalipahoinvointi

TABLE OF CONTENTS

FOREWORD

I would like to thank Essi, for her help and patience.

Oulu, 12.6.2019

Tapio Kursula

ABBREVIATIONS

FMS	Fast Motion sickness Score
HMD	Head-Mounted Display
LOCF	Last Observation Carried Forward
MSSQ	The Motion Sickness Susceptibility Questionnaire
SSQ	Simulator Sickness Questionnaire
VIMS	Virtually Induced Motion Sickness
VR	Virtual Reality

1. INTRODUCTION

Virtual reality has tremendous potential for a vast array of applications ranging from mental illness treatment to entertainment use. Cybersickness is a condition similar to motion sickness that can affect people who are immersed in a virtual reality. Cybersickness has been studied for multiple decades and a large part of its research base comes other, older areas of motion sickness studies, such as simulator sickness studies. In simulator sickness studies questionnaires have been the de facto method of gathering data about simulator sickness. Questionnaires have been the main data gathering method in cybersickness studies as well. [1]

Although the exact cause of cybersickness remains unknown, there has been evidence that level of visual detail correlates with the perceived cybersickness [2-4]. In this thesis, a data collection was done to compare two scenes with different levels of visual detail. The purpose of the study was to gather data for later analysis. The perceived level of cybersickness was assessed with questionnaires. Various sensor data were also collected and the point-of-view of the subject in the virtual scene was recorded.

This thesis presents the data collection methods and results related to cybersickness. The goal of the data was to address the following research question: “Is the level of perceived cybersickness associated with the amount of visual detail in virtual environments?”. The thesis covers an overview of the theoretical background of cybersickness, an outline of the data collection methods, the results, and the conclusions.

1.1. Contributions

The study design specification, data collection, and data analysis included in this thesis were mainly carried out by Tapio Kursula, BSc (tech) student. Toni Kuosmanen, BSc (tech) focused on carrying out a digital image analysis of visual content in his thesis, which is why he contributed to study design, data collection, and virtual scene implementation. The thesis was supervised by Matti Pouke, PhD. The sensor equipment was provided by VTT, Technical Research Centre of Finland and the study was carried out in the Ubicomp laboratory in the University of Oulu.

2. THEORETICAL BACKGROUND

2.1. Virtual Reality and Vection

Virtual Reality, often abbreviated VR, has been described by William R. Sherman & Alan B. Craig (2018) as follows:

> *”Virtual reality: a medium composed of simulations that sense the participants position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)”*

Presently the main sense being replaced in Virtual Reality is the sense of vision. Because of this visual input, exposure to VR may trigger a condition named cybersickness. Cybersickness is a subcategory of Visually Induced Motion Sickness, or VIMS: a sensation that is similar to traditional motion sickness (MS), the difference being that the stimuli are visual and there is either limited or no physical movement involved [5]. An illusion of self-movement can be achieved through the visual stimuli. The origin of the visual stimuli in cybersickness include virtual environments in, among others, head-mounted displays (HMD), Computer Assisted Virtual Environments (CAVE), curved screen systems, and large screens [1]. Although cybersickness itself has been studied for about four decades, a large part of its background comes from MS, VIMS, and simulator sickness studies. There is quite a bit of overlap between these fields and the lines between them are often hard to define. In this thesis, examples of studies from all the aforementioned research areas are referenced.

The illusion of self-motion in the absence of physical motion is called vection [6]. Vection occurs when a large part of the visual field moves, creating a moving sensation. For instance, vection may occur when viewing a wide field of view display, which is the case with VR systems [5]. Vection is not only limited to virtual environments but can also be experienced in non-virtual context as well. A well-known example of real-world vection is called the train illusion; when a person in a train station sees a nearby train moving they can have an illusion of moving to the opposite direction [7]. Vection can be categorized into linear and circular vection. Linear vection is a feeling of self-translation and circular vection is a feeling of self-rotation [8]. The train illusion is an example of linear vection. An example of circular vection could be the commonly used experiment method in which the subject is seated inside of a rotating drum, the inside of which is filled with alternating black and white stripes; after a while, the subject experiences a feeling of rotation [8].

2.2. Causes of Sickness

Although MS and VIMS have been studied for relatively long, the exact reasons as to why they happen are not known. They seem to be polygenic in nature, having multiple origins. There are three prevalent theories for the causes of the symptoms: sensory conflict theory, postural instability theory, and poisoning theory. [1]

According to sensory conflict theory, VIMS and MS occur when there is a sensory conflict between the vestibular and the visual system, for example when the visual system thinks one is moving and the vestibular system thinks one is not. Sensory conflict theory is considered to be the oldest and it is the most studied theory. There are limitations to it, however. For example, it has poor predictive power of conditions or the severity of the symptoms, it doesn't explain why some people get sick and others don't when exposed to identical stimuli, and it doesn't explain why sensory conflict causes sickness. Furthermore, there is currently no objective method to measure sickness from the standpoint of this theory; instead, subjective measurement tools, such as questionnaires, are used. [9, 10]

The second theory is the postural instability theory. According to it, motion sickness is caused by the lack of postural stability, which is defined as the uncontrolled movement of the perception and action systems. It offers a more objective evaluation of motion sickness since the postural sway can be measured. There has been, however, a study which found that there is a time lag between the subjective symptoms and the postural sway, the subjective symptoms appearing first, suggesting opposite causal relationship. It remains, nonetheless, the sole theory that makes objective measurements possible, and has been recently gaining popularity. [9, 11]

The third theory is poisoning theory, which takes an evolutionary standpoint to explain motion sickness. It states that ingesting poison causes physiological effects that occur in the visual and vestibular systems. In this situation an emetic response would be beneficial as it would prevent further poisoning. When using VR systems (or being subject to other sources of vection), input to the visual and vestibular systems may be similar to the effects of poison, thus causing similar symptoms. Like the sensory conflict theory, it lacks in predictive power, and doesn't explain why some people get sick while others don't. [12]

The amount of visual details might affect the onset of cybersickness. A metric called spatial velocity has been made to quantify the amount of visual details in a scene. It is calculated from average spatial frequency and scene movement velocity; capturing the scene's visual complexity and its movement relative to the participant.[2]

2.3. Measurements

2.3.1. Motion Sickness Susceptibility Questionnaire

Motion Sickness Susceptibility Questionnaire [13], abbreviated as MSSQ, can be used for assessing the sensitivity to motion sickness. The MSSQ exists in two forms, often referred to as MSSQ-Long and MSSQ-Short. The questionnaire is designed to assess individual's sensitivity to motion sickness and the type of motion sickness that is the most effective in causing the motion sickness. As this thesis uses the short version, only this version is explained further. [14]

The MSSQ-Short consists of four sections. The first two are the age and sex of the individual. In the third section, the individual is asked how often they have felt sick or nauseated in nine types of transport or entertainment, such as cars, buses, and playground swings, before the age of 12. The frequency of sickness is grouped into five categories: *not applicable/never travelled*, *never felt sick*, *rarely felt sick*, *sometimes felt sick*, and *frequently felt sick*. The fourth section is the same as the third one, except that the individual is asked how often they felt sick or nauseated over the last 10 years. [14]

The scores for both childhood and the last 10 years are calculated in the following way: The categories *never felt sick*, *rarely felt sick*, *sometimes felt sick*, and *frequently felt sick* are given number scores from 0 to 3, respectively. The *total sickness score* is the sum of number scores in all types (total of 9 types). The total amount of *not applicable/never travelled*, is calculated (with a maximum of 9). The susceptibility score for each category is then calculated as follows:

$$MS = \frac{(total\ sickness\ score)\times 9}{9-(total\ amount\ of\ not\ applicable)} \tag{1}$$

The MSSQ raw score is the sum of the MS score in childhood (MSA) and during the last 10 years (MSB), i.e. MSSQ raw score = MSA + MSB. A close approximation of the percentile score can be attained using the following polynomial:

$$y = ax + bx^2 + cx^3 + dx^4, \tag{2}$$

where y is the percentile score and x is the MSSQ raw score with $a = 5.1160923$, $b = -0.055169904$, $c = -0.00067784495$, and $d = 0.000010714752$. [14]

2.3.2. Simulator Sickness Questionnaire

As cybersickness is a subjective experience, assessing the level of experienced cybersickness is most often based on surveys. One of the most commonly used survey is called Simulator Sickness Questionnaire, often abbreviated SSQ. The SSQ has been the standard research tool in cybersickness studies ever since its creation in 1993. It consists of 16 questions about symptoms of simulator sickness each rated on a scale of 0-3, 0 meaning no symptoms and 3 meaning severe symptoms.

Each question is assorted into one or more categories corresponding to a subtype of symptoms (denoted by 1 in Table 1). The subtypes of symptoms are nausea (N; nausea, stomach awareness, increased salivation, burping), oculomotor (O; eyestrain, difficulty focusing, blurred vision, headache), and disorientation (D; dizziness, vertigo). The SSQ scores for each of the categories, denoted by SSQ_N, SSQ_O, and SSQ_D are obtained by computing a sum of the scores for each category, called raw scores, and multiplying the sums with 9.54, 7.58, and 13.92, respectively. The total SSQ score, SSQ_T, is the sum of the raw scores multiplied by 3.74. [15]

Table 1. Category weights in SSQ [15]

SSQ Symptom	N	O	D
General discomfort	1	1	0
Fatigue	0	1	0
Headache	0	1	0
Eyestrain	0	1	0
Difficulty focusing	0	1	1
Increased salivation	1	0	0
Sweating	1	0	0
Nausea	1	0	1
Difficulty concentrating	1	1	0
Fullness of head	0	0	1
Blurred vision	0	1	1
Dizzy (eyes open)	0	0	1
Dizzy (eyes closed)	0	0	1
Vertigo	0	0	1
Stomach awareness	1	0	0
Burping	1	0	0

Although sicknesses under VIMS and traditional motion sickness are characterized by same symptoms, they can be differentiated. The sicknesses differ in their NOD profiles. For example, in sea sickness the N-SSQ score is the highest, O-score second highest, and D-score the lowest. This profile is noted as follows N > O > D. Similarly, space sickness has a profile of N > D > O, military simulations O > N > D profile, and cybersickness D > N > O profile. [1, 16]

2.3.3. Fast Motion Sickness Score

Fast Motion sickness Score (FMS) is a verbal rating scale to get motion sickness scores from a subject quickly. It is used during exposure to motion sickness stimulus by asking the subject to assess their sickness on a scale from 0 to 20, 0 being no sickness at all and 20 being frank sickness. The subject is prompted for the question every one or two minutes of the exposure to stimulus. The FMS is designed to score nausea and discomfort, and the peak FMS-score is shown to correlate with all SSQ sub-scores as well as with the SSQ total-score. [17-19]

3. METHODS

The goal of the present study was to assess the difference in perceived cybersickness between low-detail and high-detail scenes. Questionnaire and sensor data were collected from study subjects who were shown two virtual scenes: a realistic scene and a simplified scene.

Before the experiment, the study subjects filled out a consent form for the data gathering and participating to the experiment. Even though personal data was collected, data pre-processing was done anonymously, and people are not identifiable through the dataset itself. The planned number of participants was 23, but due to research equipment breaking down, the realized number of participants was 22. In total, six test instances were missing from the planned data set. One person missing completely (the test had two data gathering instances) and four people were missing their second data instance. This leaves total amount of 18 people that completed both tests. The questionnaire data was collected on pen and paper forms. The forms were digitalized to Excel spreadsheets. The data collection was done in November, December, and January of 2018 and 2019. The data collection plan was designed together with Matti Pouke, PhD and Toni Kuosmanen, BSc (tech).

The study design is experimental and real-time. The study was held within-subjects; each subject does the test twice with different scenes. The minimum time between individual test instances was one week to minimize carry-over effects from the previous test instance. The low-detail scene had simplified graphics whereas the high-detail scene was aimed to be more realistic. Both scenes depicted the Linnanmaa campus of the University of Oulu. The scenes had a camera object move through the scene on a fixed route and at a constant rate. The subject saw the point-of-view of the camera in the virtual scene. The subject's movement was limited to a small area within the physical laboratory, but they were free to look around, i.e. the path and the speed of the camera were fixed but the subject had control over the angle of the camera. The scenes did not include any sound. The duration of both scenes was approximately 12.5 minutes. The campus models were done on Blender, a 3D modeling software; the scenes were made with Unreal Engine, a game engine.

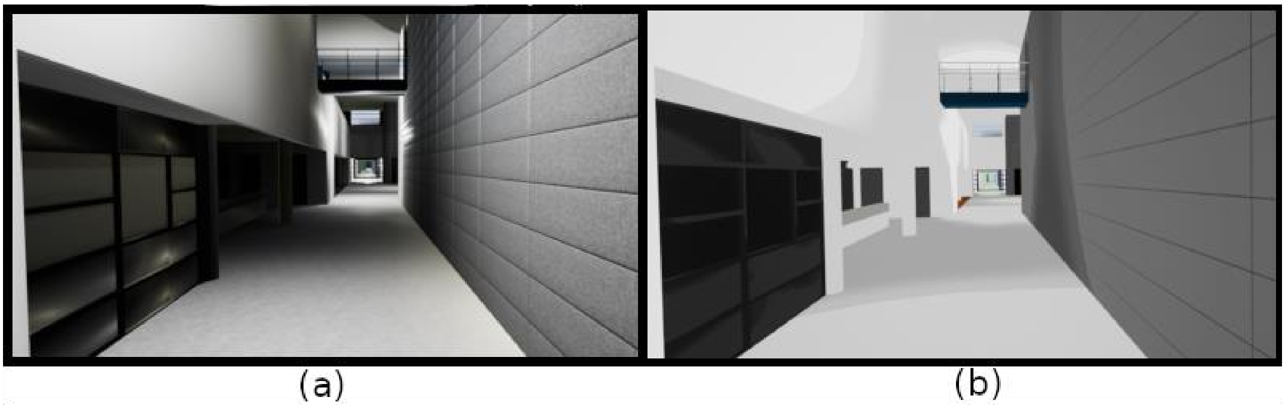

Figure 1: a comparison between the scenes (a) is the high-detail and (b) the low-detail scene

The target sample size was set to approximately 30 study subjects prior to the enrollment process. The target population consisted of both students and people with day jobs from of any age and sex to ensure heterogeneity of the study population. The potential study subjects were contacted via email and personal invitation. A recruitment email was sent to an email mailing list of the math and physics students in the University of Oulu, but no responses were received. All enrolled subjects were personally invited to participate to the study, either by me or my thesis supervisor. The flowchart for study population and sample size is presented in Figure 2.

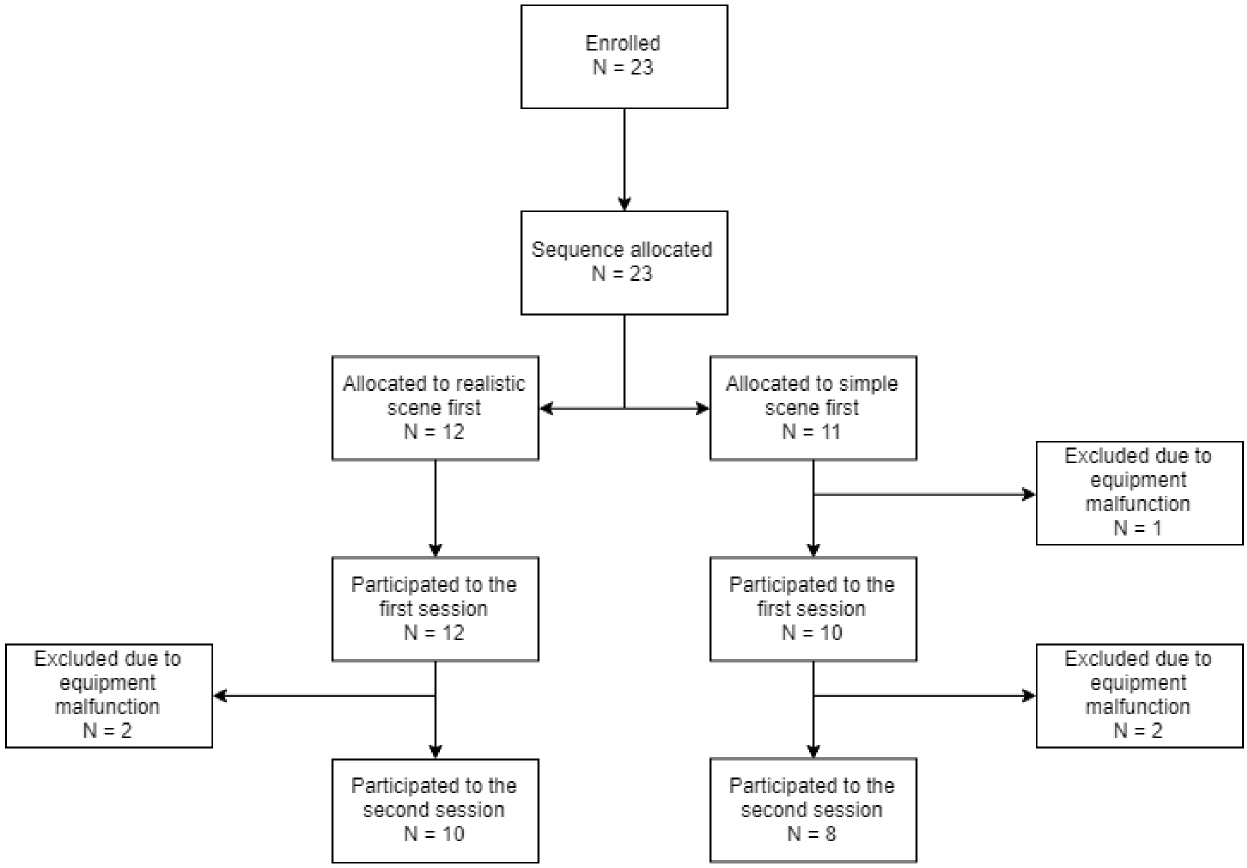

Figure 2: Flow chart of study population

Before the study sessions, subjects were assigned into two groups. One group was to be exposed to the realistic scene first and the other to the simple scene first. Two study sessions were scheduled for each study subject. Both sessions were carried out at the Ubicomp laboratory in the University of Oulu. In the first session, administered MS questionnaires were the MSSQ, before exposure to the scene; the FMS, during exposure; and the SSQ, after exposure. The second session was similar, with the exception that the MSSQ was excluded, as we already had the information gained from it. The order of the scenes was assigned for each study participant prior to conducting the study. The order was based on the unique identifiers (ID) of the study participants so that study participants with odd IDs were first shown the realistic scene and study participants with even IDs were first shown the unrealistic scene. The realistic scene was shown first for the test subject with ID number zero.

In the first session, the study participant was introduced to the study and the written consent was requested. The study participant was then asked to put the sensor devices on. The measured sensor data included, among others, heart-rate and accelerometer data and it was collected before and during the experiment. The device output was checked from the mobile device receiving the sensor data and the recording was started. After this, the subject was asked to fill in the background information form. The form included questions about demographic variables (e.g. age, educational level), previous experience from VR and 3D games, and the MSSQ-Short questionnaire. The study subject then put on the HMD device and was assisted in adjusting it to fit themselves. The study subject was asked to stand in the experiment area and raise their arm with the smart watch to mark the beginning of the experiment and the scene was initiated. The FMS was obtained every minute, the first assessment being immediately at the start of the experiment. The study participant could talk and look around freely during the experiment. After the scene ended, the subject was asked to fill in the SSQ questionnaire. An appointment for the next scene was scheduled. The questionnaire filled during the first session is presented in the appendix of this thesis.

The second session was carried out in a similar way as the first one, except for the exclusion of background information form and the MSSQ. The second scene was shown to the study participant. Depending on which scene the study participant had been shown during the first session, the remaining scene was shown. The study participant received a movie ticket voucher as a reward for their participation. Due to heart-beat sensor malfunction, data collection was not done for the second time for some of the study subjects and no data were collected from one subject.

4. RESULTS

The study population comprised of 23 participants, 22 of which participated in at least one session (N = 22). All study subjects gave their consent for participation in research and data acquisition. The age of the 22 study participants varied between 22 and 52 years with the median and mean age being 24 years and 29.5 years, respectively. Males accounted for 64 % of the study population. The most common highest completed education was bachelor's degree (N = 9), followed by master's degree (N = 5), upper secondary school (N = 4), and other (N = 4). Altogether 9 study participants were near-sighted, 8 of which reported wearing glasses or contact lenses. Most of the study participants had little or no experience in VR and most participants had either none or a lot of experience in 3D gaming, as shown in Table 2.

Table 2. Previous experience in VR and 3D gaming.

	Never	1 -4 times	5-10 times	More than 10 times
How often have you used VR glasses?	5	14	2	1
How often have you played 3D games on a PC or a gaming console?	8	5	1	8

The minimum MSSQ raw score value was 0 and maximum was 35. The median value of MS raw score was 6.75 and the mean value was 12. A histogram of the MSSQ percentile scores is presented in Figure 3. Study participant with ID 17 is excluded from the graph because of missing values.

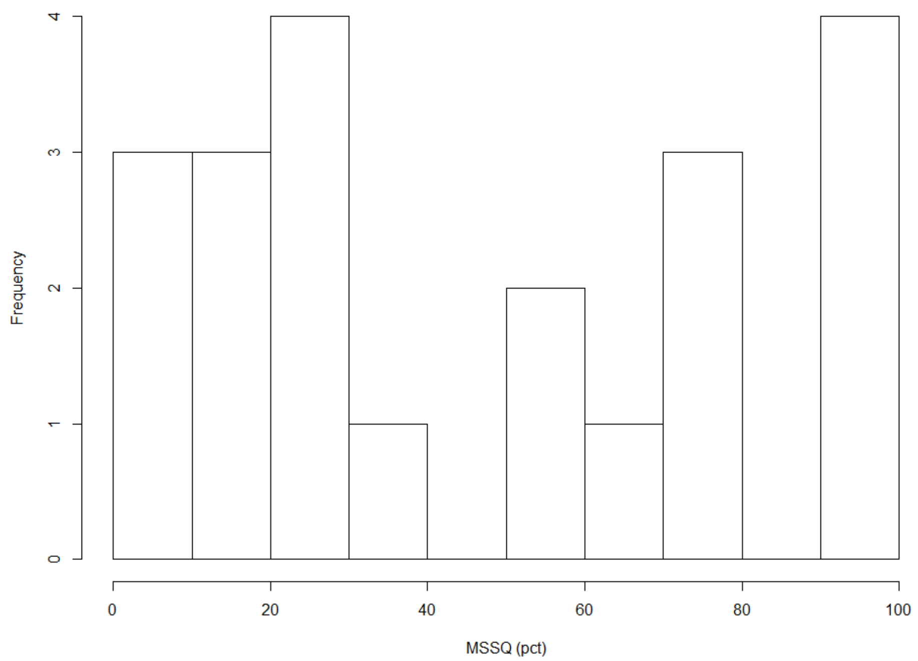

Figure 3. Histogram of the MSSQ percentile scores.

The mean FMS scores are presented in Figures 4 and 5 grouped by the scene type and the session number, respectively. As seen in Figure 4, the FMS score for the realistic scene was, at average, slightly higher than the score for the simplified scene. Both scenes show a rise in score at 10-minute mark. In the scenes, this was after a rapid successive decline and ascension of stairs. In Figure 5, it is shown that, on average, FMS scores were decreased in the second session, except for the last measurement.

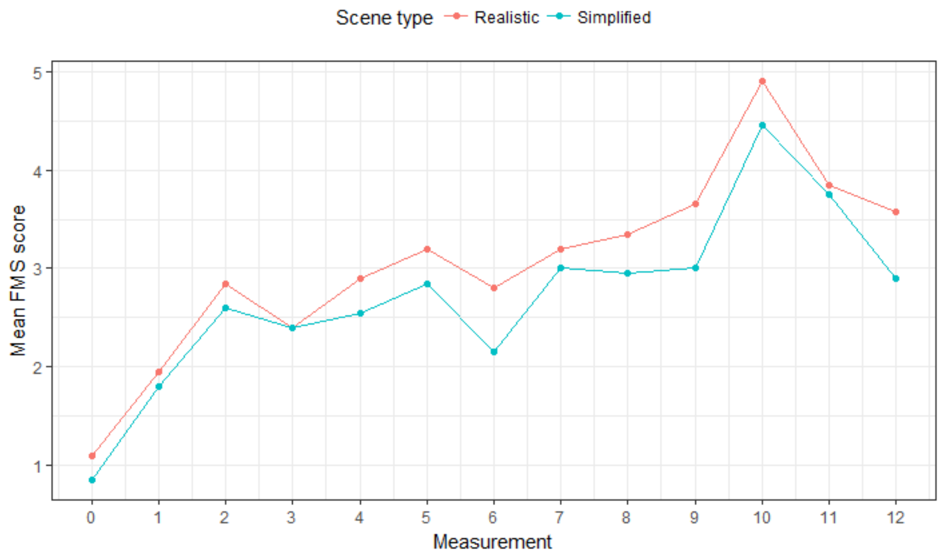

Figure 4. Mean FMS scores by scene type. Missing values were omitted.

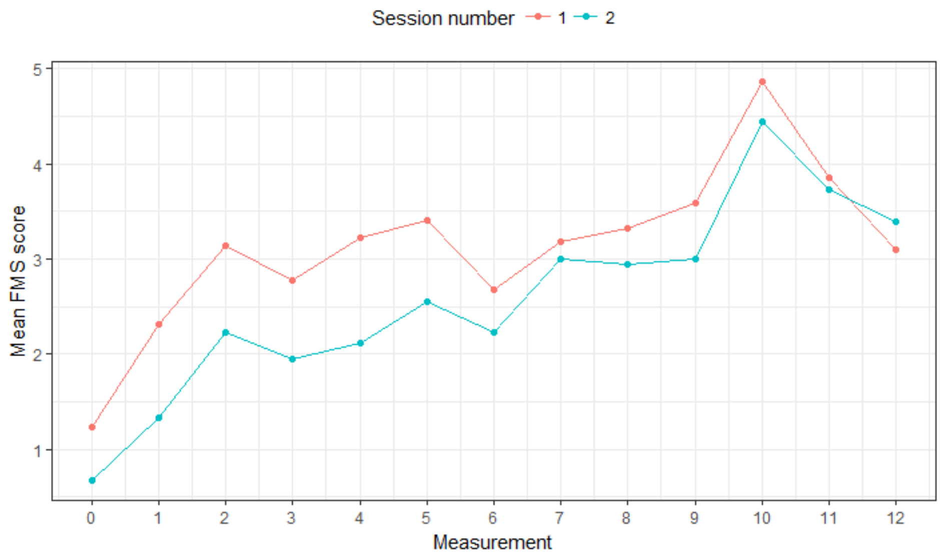

Figure 5. Mean FMS scores by session number. Missing values were omitted.

In Table 4, SSQ statistics between the realistic scene and the simplified scene are shown. Overall, subjects reported the highest scores in the disorientation category, SSQ-D. Furthermore, the simplified scene had the largest SSQ-D scores out of the two scenes. Variation between subjects was higher than in realistic in all categories including the total score. The realistic scene had slightly higher nausea scores. Oculomotor scores were reported the lowest out of all scores.

Table 3. SSQ statistics between the realistic scene and the simplified scene. Results are represented as mean (standard deviation). Missing values were omitted.

	Realistic scene (N = 20)	Simplified Scene (N = 20)
SSQ-N	37.7 (34.3)	35.8 (39.0)
SSQ-O	22.4 (15.5)	22.4 (23.0)
SSQ-D	59.2 (39.9)	61.9 (53.9)
SSQ-T	41.7 (26.8)	41.7 (37.8)

Figure 6 shows a scatterplot of peak FMS scores and SSQ-N scores. The two parameters appear to be linearly related to each other; the higher the peak FMS score, the higher the SSQ-N score. The association is visible among the realistic scene as well as the simplified scene.

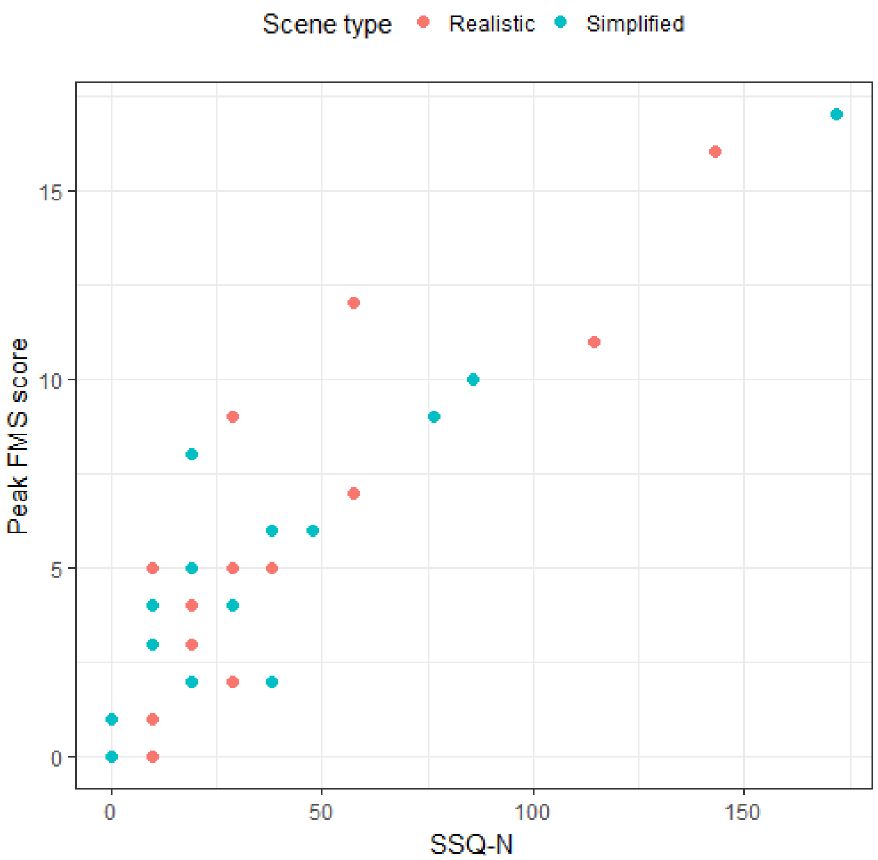

Figure 6. Scatterplot of peak FMS scores and SSQ-N scores.

5. DISCUSSION

The goal of the thesis was to collect data for evaluating the association between cybersickness and the amount of visual detail. Questionnaire and sensor data were collected from study subjects who were shown two virtual scenes: a realistic scene and a simplified scene.

The data covered 40 data collection sessions with 22 study participants. Although the sample size was relatively small, a variety of demographics were represented in the sample; the study population consisted of subjects of different ages, sexes, and educational backgrounds. The study participants were shown two scenes: a realistic scene and a simple scene. The order of the scenes was randomized to ensure that the results were not affected by the sequence allocation. Some of the study subjects did not attend to both sessions.

Missing data was caused by premature trial termination due to discomfort experienced by the study subject. Consequently, the amount of missing data could have been minimized by either continuing the trial despite subject discomfort, which could be considered unethical, or by trying to make the experiment less nauseating, which could not be applied due to the nature of the study. In this thesis, missing values were omitted in all analyses. Last observation carried forward (LOCF) imputation method was not applied, despite its popularity, as studies applying LOCF have been criticized for being of questionable veracity [20]. However, omitting missing values may also have introduced bias to the results.

The results of the analysis indicate that there might be a difference in the perceived cybersickness between the simple and the realistic scene which was indicated by both FMS and SSQ scores. The FMS scores were slightly higher in the realistic scene when compared to the simple scene. However, omitting missing values in the line graphs may have resulted in underestimation of the FMS scores because missing values indicate that the study subject had to terminate the experiment because of discomfort. The realistic scene also appeared to cause more nausea symptoms. Out of all SSQ subcategories, the nausea subcategory was the only one showing any difference between the realistic and the simple scene. However, a larger sample size is required to draw any further conclusions.

Some of the study participants did not attend to the second experiment session. It could be that the study participants were hesitant to come to the second session because of a high level of discomfort during the first exposure.

Cybersickness is a subjective condition, and measuring such condition reliably is difficult. Moreover, most of the study subjects were Finnish and were presented with a translated version of the SSQ and MSSQ. This might introduce bias because of subtleties in language.

Although initial results indicate that there might be an association between cybersickness and the amount of visual detail, further analysis and data collections with larger sample sizes are required to derive reliable and generalizable results.

6. CONCLUSION

Cybersickness is a condition similar to traditional motion sickness which can affect users immersed in virtual reality. It has been studied for multiple decades, and has its roots in other motion sickness studies, such as simulator sickness studies. The exact cause of it is still unknown; although, the amount of visual details seems to have an effect on it. Questionnaires are a prevalent method of gathering data about cybersickness. Popular questionnaires include the MSSQ, SSQ, and FMS. The goal of the current study was to gather data for later analysis to answer the question: "Is the level of perceived cybersickness associated with the amount of visual detail in virtual environments?". Study participants were shown two scenes, one high and one low in visual detail. Data was gathered with questionnaires and sensor equipment from 22 participants.

FMS and SSQ scores indicate that there might be a difference between the two scenes. FMS scores were, on average, higher in high visual detail scene. The missing values were omitted however, and this might have introduced bias into the data. The N-SSQ scores were also somewhat higher in high visual detail scene. For future work, further analysis on the data would be necessary; also, it would be beneficial to repeat the experiment with a higher number of participants. Replicating the study with postural sway measurements might also be useful.

7. REFERENCES

[1] Rebenitsch L & Owen C. (2016) Review on Cybersickness in Applications and Visual Displays. Virtual Real. 20(2): 101–125.

[2] So RHY, Ho A & Lo WT. (2001) A Metric to Quantify Virtual Scene Movement for the Study of Cybersickness: Definition, Implementation, and Verification. 10(2).

[3] Davis S, Nesbitt K & & Nalivaiko E. (2015) Comparing the Onset of Cybersickness using the Oculus Rift and Two Virtual Roller Coasters. in Proceedings of the 11th Australasian Conference 27: 30.

[4] Pouke M, Tiiro A, LaValle SM & Ojala T. (Mar 2018) Effects of Visual Realism and Moving Detail on Cybersickness. : IEEE: 665-666.

[5] LaViola J, Joseph. (2000) A discussion of cybersickness in virtual environments. ACM SIGCHI Bulletin 32(1): 47-56.

[6] Seno T, Yamada Y & Palmisano S. (2012) Directionless Vection: A New Illusory Self-Motion Perception. i-Perception 3(10): 775-777.

[7] Seno T & Fukuda H. (2012) Stimulus Meanings Alter Illusory Self-motion (Vection) - Experimental Examination of the Train Illusion. Seeing and Perceiving 25(6): 631-645.

[8] Palmisano S, Allison RS, Schira MM & Barry RJ. (2015) Future challenges for vection research: definitions, functional significance, measures, and neural bases. Frontiers in psychology 6: 193.

[9] Warwick-Evans LA, Symons N, Fitch T & Burrows L. (1998) Evaluating sensory conflict and postural instability. theories of motion sickness. Brain Research Bulletin 47(5): 465-469.

[10] Stoffregen TA & Riccio GE. (1991) An Ecological Critique of the Sensory Conflict Theory of Motion Sickness. Ecological Psychology 3(3): 159-194.

[11] Stoffregen TA & Smart LJ. (1998) Postural instability precedes motion sickness. Brain Research Bulletin 47(5): 437-448.

[12] Oman CM. (2012) Are evolutionary hypotheses for motion sickness "just-so" stories? J Vestib Res 22(2): 117-127.

[13] Golding JF. (1998) Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. Brain Research Bulletin 47(5): 507-516.

[14] Golding JF. (2006) Predicting individual differences in motion sickness susceptibility by questionnaire. Personality and Individual Differences 41(2): 237-248.

[15] Kennedy RS, Lane NE, Berbaum KS & Lilienthal MG. (1993) Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. International Journal of Aviation Psychology 3(3): 203.

[16] Robert S.Kennedy, Julie Drexler & Robert C.Kennedy. (2010) Research in visually induced motion sickness. Applied Ergonomics 41(4): 494-503.

[17] Keshavarz B & Hecht H. (2014) Pleasant music as a countermeasure against visually induced motion sickness. Applied Ergonomics 45(3): 521-527.

[18] Keshavarz B & Hecht H. (2012) Stereoscopic Viewing Enhances Visually Induced Motion Sickness but Sound Does Not. Presence: Teleoperators & Virtual Environments 21(2): 213-228.

[19] Keshavarz B & Hecht H. (2011) Validating an efficient method to quantify motion sickness. Hum Factors 53(4): 415-426.

[20] Lachin JM. (2016) Fallacies of last observation carried forward analyses. Clinical Trials 13(2): 161-168.

APPENDICES

Appendix 1. Cybersickness questionnaire

Appendix 1. Cybersickness survey

Cybersickness survey

Tapio Kursula (jussi.kursula@student.oulu.fi)
Toni Kuosmanen (toni.kuosmanen@student.oulu.fi)

Before the experiment

1. Please state your age: _____

2. Please state your sex: ☐ male ☐ female ☐ other

3. Please state your highest complete education level:

☐ Upper secondary school (lukio, ammattikoulu)
☐ Bachelor's degree
☐ Master's degree
☐ Other, what ________________________________

3. Do you wear glasses or contact lenses? ☐ Yes ☐ No

If you aswered No to question 3, please move to question 4.

3A. Are you ☐ near-sighted (-), ☐ far-sighted (+), or ☐ both?

3B. Please state your (approximate) prescription. Left: ____ Right: ____

4. How often have you used VR glasses?
☒ Never ☐ 1-4 times ☐ 5-10 times ☐ More than 10 times

5. How often have you played 3D games on a PC or a gaming console?
☐ Never ☐ 1-4 times ☐ 5-10 times ☐ More than 10 times

6. As a CHILD (before age 12), how often you felt sick of nauseated (tick boxes):

	Not applicable, never travelled	Never felt sick	Rarely felt sick	Sometimes felt sick	Frequently felt sick
Cars					
Buses or coaches					
Trains					
Aircraft					
Small boats					
Ships, e.g. channel ferries					
Swings in playgrounds					
Roundabouths in playgrounds					
Big dippers, funfair rides					

7. Over the LAST 10 YEARS, how often you felt sick or nauseated (tick boxes):

	Not applicable, never travelled	Never felt sick	Rarely felt sick	Sometimes felt sick	Frequently felt sick
Cars					
Buses or coaches					
Trains					
Aircraft					
Small boats					
Ships, e.g. channel ferries					
Swings in playgrounds					
Roundabouths in playgrounds					
Big dippers, funfair rides					

Questions 6 and 7 are based on Motion Sickness Susceptibility Questionnaire Short-form (MSSQ-Short).

After each experiment

1. Realistic grahics

	None	Slight	Moderate	Severe
General discomfort				
Fatigue				
Headache				
Eye strain				
Difficulty focusing				
Salivation increasing				
Sweating				
Nausea				
Difficulty concentrating				
Fullness of the head				
Blurred vision				
Dizziness with eyes open				
Dizziness with eyes closed				
Vertigo				
Stomach awareness				
Burping				

2. Simplified grahics

	None	Slight	Moderate	Severe
General discomfort				
Fatigue				
Headache				
Eye strain				
Difficulty focusing				
Salivation increasing				
Sweating				
Nausea				
Difficulty concentrating				
Fullness of the head				
Blurred vision				
Dizziness with eyes open				
Dizziness with eyes closed				
Vertigo				
Stomach awareness				
Burping				

The questions are based on Simulator Sickness Questionnaire (SSQ) by Kennedy, Lane, Berbaum, & Lilienthal (1993)