Bachelor thesis

Balancing the virtual reality experience

A study of human reactions with the Oculus Rift DK2

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HINT

Abstract

We have researched why people react differently while using the Oculus Rift and tried to find key factors that affects the user considering simulation sickness. We also wanted to look for a pattern or a certain group of users that is more exposed.

The respondents participating tested a demo with the Oculus Rift, while we wrote down observations of their physical reactions during the test. After the demo, the respondents answered a survey.

The results of the collected data show that there is a certain group of users that is more exposed to get symptoms of simulation sickness. There is a connection between earlier experience with motion sickness and experiencing simulation sickness with the Oculus Rift.

People in the age group 31-40, with a lower interpupillary distance than average and who often get sick travelling by car/bus are a target group more exposed to get symptoms of simulation sickness.

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Sammendrag

Vi har undersøkt hvorfor mennesker reagerer forskjellig når de bruker Oculus Rift, og sett om det er noen nøkkelfaktorer som påvirker de når det kommer til simulasjonssyke. Vi ønsket også å se om det er en spesiell gruppe som er mer utsatt.

Respondentene som deltok, testet en demo med Oculus Rift og vi noterte observasjoner av deres fysiske reaksjoner under testen. Etter demoen svarte de på en spørreundersøkelse angående opplevelsen.

Resultatene fra innsamlet data viser at det er en gruppe mennesker som er mer utsatt for å oppleve simulasjonssyke. Det er en sammenheng mellom tidligere erfaringer med bevegelssesyke og simulasjonssyke.

Mennesker i aldersgruppen 31-40, med en pupillavstand under gjennomsnittet og som ofte blir bilsyk er en målgruppe mer utsatt for å oppleve symptomer til simulasjonssyke.

1 Introduction

In this project we have had focus on 3D goggles and the experience using this technology.

We have always been interested in the different reactions people have to the visual content presented when gaming, whether it's on console or PC.
Choosing this project and the research questions gave us an opportunity to monitor people's reactions to a certain experience using the Oculus Rift virtual reality goggles.

Seeing as we have different personal experiences when it comes to reactions to video games and 3D, we felt highly motivated to start this project as we were curious to see the results. Is there a pattern or a certain group of users that are more exposed?

Virtual reality (VR) goggles and 3D simulation is currently a hot topic and will soon be available for public use. We want to keep ourselves updated on the development of this technology and we are excited for the possibilities in the future.

Acknowledgements:

We have had a lot of help and theoretical input, and would like to mention the people who made this project possible.

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Sebastian Kuhlen

All respondents for participating.

2 Research questions

This project examines the use of Virtual Reality goggles in entertainment and simulation applications focusing on the user experience. We want to examine how different groups of users react to using 3D rendering hardware like the Oculus Rift VR goggles and will be studying how people react to a chosen experience, monitoring their physical and emotional responses during and after the experience.

We also want to investigate if it is possible to establish a set of guidelines for developers to adhere to which ensures that the target audience will not experience severe simulation sickness symptoms.

Research question 1: How does different groups of users react to the usage of the 3D rendering hardware Oculus Rift VR goggles?

Research question 2: Is there a pattern or a certain group of users that is more exposed?

Research question 3: Is it possible to establish a set of guidelines for developers to ensure that the target audience won't experience severe simulation sickness symptoms during/after the experience with VR googles?

2.1 Explanation and limitations

To make sure the reach of this project is not too wide, we have to give ourselves reasonable boundaries for the research questions. The focus in this thesis is the user experience, which means observing the respondents, write down what they say and how they react. The term "Virtual Reality goggles" means the Oculus Rift Development Kit 2, which was the chosen virtual reality headset for this project. The chosen experience, or simulation application, is a rollercoaster demo called Atlantis Infinite Coaster.

The guidelines will be "rules of thumb".

3 Theory Chapter

In this chapter we will clarify different topics in the groundwork for the research. It is important to have a fundamental understanding of some of the processes the body goes through while experiencing 3D simulation. Topics this chapter cover includes physical reactions generated by 3D projection and an explanation of some technical terms related to the use of Oculus Rift VR goggles.

3.1 Motion and simulation sickness

You will be given a brief overview over the anatomy of how the body detects movement. Secondly, an explanation of motion sickness and simulation sickness is given, followed by a definition of "rift sickness".

3.1.1 Human body detecting movement

The brain is always gathering and analyzing data received from the body. When the body is running, signals from the eyes and the inner ear tells the brain that the body is in movement. If a person is running, the brain recognize every signal in a balanced way, so the person will not feel any discomfort. But when the brain receive mixed signals, the motion sickness can kick in (Draper, 1996).

Vestibular System (Inner ear)

The vestibular system, also known as the inner ear, is the most important factor when it comes to experiencing motion and simulation sickness. The fluid in the inner ear detects head movement and is central when it comes to balance (i.e. equilibrium).

Visual Receptors (Eyes)

The receptors, also known as eyes, tells the brain where the body is currently located and if it is in motion. They recognize if the body is in a standing position, upside down, tilting or in other positions, through the objects around it.

Proprioceptors

This is basically the rest of the human body. There are sensors located in the skin, joints and muscles that inform the body how your limbs are positioned.

Brain

The brain use the received data from the inner ear and eyes and process this to the rest of the body. For example, when you are walking on a line, the eyes will tell how the environment is, the inner ear tells the brain about its movement and balance. The brain will then analyze the received data and tell the rest of the body how to act to avoid falling off. All this happens on a subconscious level.

3.1.2 Motion sickness

Motion sickness is also called travel sickness, and can occur when traveling by road, air, rail or sea. It occurs when there is a conflict between the motions your eyes and inner ear detects. (Davis, 2014).

Example 1: Your eyes sense movement while traveling with bus, but the inner ear tells the brain there is no equal movement to the message from the eyes.

Example 2: You are in a cabin on a ship and your inner ear detects movement on the sea, but your eyes do not detect the movement inside the room. (Motionsickness.net, undated).

When the brain gets mixed signals, it affects your balance sense, and it reacts by sending misleading signals to the body and you can feel sick and dizzy. Your brain behaves like you are poisoned (Treisman, 1977) and the body goes into a defensive mode and tries to get the poison out by causing nausea and sweating.

Detects movement:

Brain	Inner ear	Eyes	Body
	x	x	

3.1.3 Simulation sickness

Simulation sickness is often mistaken for motion sickness, but is in theory the opposite of it. Your visual receptors sense motion, but the vestibular system and proprioceptors tells the brain there is no motion. The brain gets confused and you experience the same symptoms/side effects as in motion sickness; nausea, dizziness and losing balance. This is also called "visually induced motion sickness" (VIMS) and can occur while playing videogames or watching movies (So & Ujike, 2010, p 491).

Detects movement:

Brain	Inner ear	Eyes	Body
		x	

3.1.4 «Rift sickness»

This is the same as simulation sickness. It was common to feel ill after the usage of the Oculus Rift DevKit 1 that the users gave the feeling the name "Rift sickness" on Oculus forums (Oculus VR forum, 2015). On the forum the users discuss what might be the cause and how to prevent it. Many think there's a link between low framerate and incorrect interpupillary distance settings (IPD) (see section 3.2.2). They also think light settings need to be adjusted properly to avoid headache. They share tips and theories how to avoid "rift sickness", everything from eating ginger, tape vibrating toys the headset, drink a beer before usage or shake your legs while using the Oculus to simulate restless legs.

3.2 The visual system and 3D projection

The visual system and especially how the eyes receive information is very important when it comes to virtual environments like the virtual reality headset Oculus Rift.
Creating functional goggles is not an easy task as there are several factors to consider, as the visual system is complex and the facial proportions among users/individuals vary.

In this chapter we will take a closer look at some of the important matters regarding how the visual receptors work and how it affects the use of virtual reality goggles.

3.2.1 Visual receptors

We need a basic understanding of how the eye uses light to project visual content to be able to understand what the eye perceives when using virtual reality goggles.

When light enters through the eye, it first enters through the cornea which is the eye's "window" and main focusing element. The cornea bends light to be sent through the pupil and the pupil will adjust its size to control how much light that should strike the lens. The lens will focus the light to be sent to the back of the eye to the retina.

An important part of the retina is called fovea centralis, and is responsible for details and sharp vision. The retina will change the light into electrical impulses and send them to the optical nerves which in turn sends the signals to the visual cortex in the brain, where an image is perceived. The view from each eye is slightly different and our brain combines them into a single three dimensional stereoscopic image, an experience known as stereopsis. (Montgomery, 2015a; Montgomery, 2015b; Montgomery, 2015c; National Keratoconus Foundation, 2015; St. Luke's Cataract & Laser Institute, 2015; Oculus VR, 2015a p. 11)

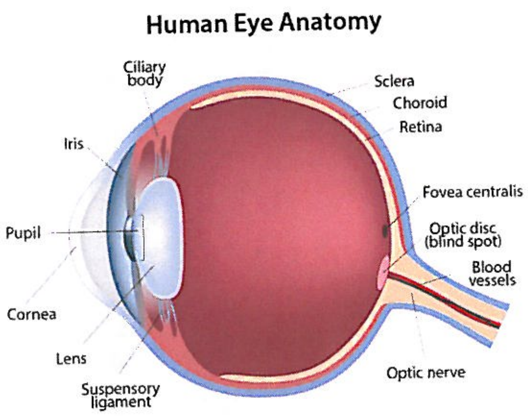

Figure 1: Illustration of the human eye anatomy (North Cascade Eye Associates, 2015)

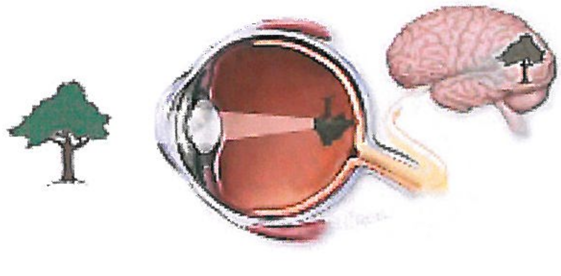

Figure 2: Illustration of how the eye perceives light and how the brain projects the impulses sent from the eye. (Bionic Vision Australia, 2015)

To see with one eye is called monocular view and using both eyes binocular view. (Kolasinski, 1995). The Oculus Rift use two virtual cameras to create one image (usually) and is considered a binocular head mounted display.

3.2.2 Interpupillary distance (IPD)

Interpupillary distance is the distance between the center of the pupils.
The ANSUR database of physiological measurements contains an IPD study of 3976 human subjects, both male and female. Considering these collected data, it is said that IPD is known to vary with respect to age, gender and race. (Dogson, 2004)

Average IPD for an adult male is 64.7 mm and 62.3 mm for females (Gordon et al., 1988, p. 209). The vast majority of adults have an IPD between 50-75 mm.

IPD is critical for design when it comes to binoculars, night vision goggles, stereoscopic displays and any other type of microscope (Dogson, 2004; UCL Department of Geography, 2015). Usually measured IPD is “infinity IPD”, which means the eyes are parallel to look at an object far away. (Kreylos, 2015)

3.2.3 3D perception

The reason why knowing a person’s IPD is important when it comes to 3D displays and virtual reality goggles, is how the image projected by the software is received by the eyes.

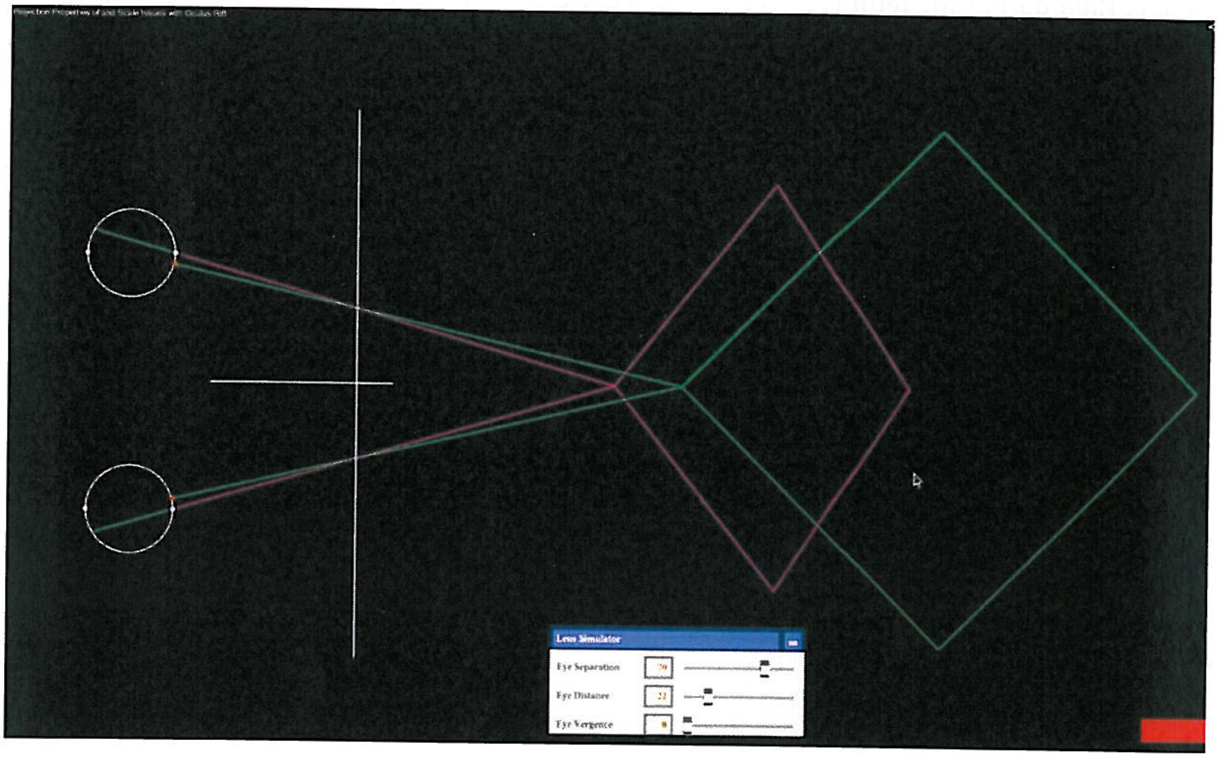

Figure 3: Screenshot from a youtube video of a lens simulator (Kreylos, 2014).

In figure 3, US Davis researcher Oliver Kreylos shows how the eyes will wrongly perceive an object through a head mounted display if the computer software IPD does not match the human’s real IPD. (Note that this is without lenses).

The green object is the virtual 3D object created by the computer and demonstrates what the object looks like and also how it would be projected by the brain if the human’s IPD was 64mm.

The purple object shows how the brain actually projects the image from the light received by the virtual (green) object. Since the programmed input from the software believes the IPD is 64mm but the human's actual IPD is 70mm, the image the brain projects gets distorted because the light from the object is programmed to hit the eyes at another spot.
The distortion that the brain perceives will make the brain believe it is being poisoned and can cause nausea. (Kreylos, 2014; Treisman, 1977)

The retina's resolution is not uniform, which means that only the area around the fovea centralis will be high resolution but it will be gradually lower further away from it. This means that if the light from the computerized object does not hit the pupil correctly, the pupil will not send the light directly to the fovea and the image will be somewhat blurred depending on where the light actually hits (Kreylos, 2014).

Obviously a head mounted display without lenses would not be suitable in reality but the illustration works to demonstrate IPD versus virtual 3D objects. However, the same principles apply when you add lenses in between screen and eyes (Kreylos, private email, attachment 1).

Perception with lenses

In a private e-mail from researcher Oliver Kreylos where he explains why it is important to add lenses in virtual reality goggles.

> *"The first part is that the lenses optically project the screens out to infinity (or 1.3m for the Rift DK2), so that the viewer can actually focus on them."*
>
> (Oliver Kreylos, email, January 25th 2015)

This explains why it is important to add lenses, meaning it is actually possible for the viewer to see the screen properly. The Oculus Rift's lenses are placed approximately at the correct distance (for most users) but they might not exactly match the user's IPD measurements. (Oculus VR, 2015b, p. 28)

> *"The second lens effect is a magnification of the screen, so that the actual field of view is somewhat larger than the FOV without lenses, but that effect is smaller than many people assume. The DK2's (theoretical) FOV without lenses is around 75 degrees, and with lenses around 100 degrees."*
>
> (Oliver Kreylos, email, January 25th 2015)

3.2.4 Depth perception

As briefly explained in section 3.2.1, the eyes need to work together simultaneously in stereopsis for the brain to be able to project a 3D image. This is also called depth perception.

Depth perception is the ability to visually judge the distance between objects and it allows us to move with precision.

Depth perception helps us to measure the size of an object, catch a ball, to drive a car or to pour water into a glass. (Optometrists Network, 2015a; Optometrists Network, 2015b)

Total or partly loss of stereoscopic vision and binocular depth perception is called binocular vision impairment. This means that the eyes do not work together as they should and there are several medical conditions that can cause diversions or misalignments.

To mention a few of the most common known to the public; strabismus (The eyes do not focus in the same direction, also called "cross-eyes"), reduced vision, astigmatism or amblyopia ("lazy eye"). (Optometrists Network, 2015c)

> *"People with poor to no stereoscopic vision will have problems with depth perception as well as the ability to see in 3D; in real life and in technology created perceptions."*
>
> (Optometrist Richard Nilsen, personal conversation, 27th January 2015)

3.3 3D rendering

To understand more of the virtual reality world and how it works, one would need at least some basic technical knowledge. This includes frame rate and what role it has for the experience, as well as display resolution, field of view, latency, vertical synchronization and timewarp. All of these things are important when using the Oculus Rift as well as for development of applications.

3.3.1 Frame rate (FPS)

All videos used in film, games and computer graphics are made by a sequence of images displayed rapidly. Every image in this sequence is called a frame, and the frame rate is the frequency of how many frames are shown per second, commonly known as frames per second (FPS). The brain needs at least 15 FPS to believe that what it sees is actually moving (Clarkson, 2009). Frame rate is measured in Hertz (Hz).

What framerate does Oculus Rift Development Kit 2 operate with?

The Oculus Rift DK2 works at 75, 72 and 60 Hz, meaning it can have up to 75 FPS (Oculus VR, 2015c). However, you need a powerful graphics card to reach a steady fps at this rate. If the computer used do not meet the minimum technical specification requirements, a drop in framerate can occur and latency can become a problem. (Oculus VR, 2015a, p. 31)

3.3.2 Display Resolution

Display resolution tells how many pixels there are in a spatial frequency in a picture (Cornell University Library Research department, undated). Every screen made has a number of distinct pixels in each dimension. It is usually informed in "width x height" and with the measure unit pixels. Resolution also tells how many "dots-per-inch" (dpi), or "pixel-per-inch" (ppi), a screen or image has. (Golben, 2014).

In other words, with a high dpi, the result is a high quality picture with high detail level. An image with low resolution could let you see the pixels as squares and the monitor image can occur as low detailed. See figure 4.

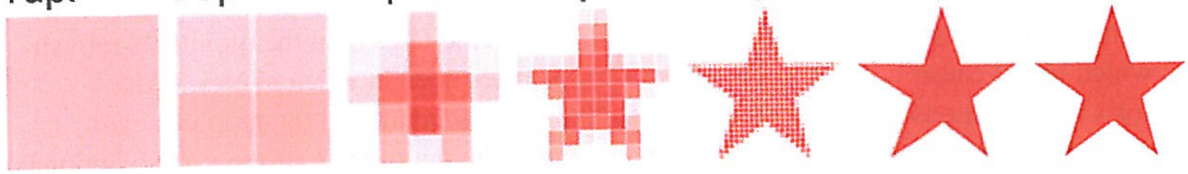

Figure 4: Illustration of high and low resolution. (Golben, 2014)

3.3.3 Field of view (FOV)

Field-of-view is defined as the horizontal and vertical angular dimensions of the display (Kolasinski, 1995). The Oculus' *Best Practices Guide* will give both users and developers helpful input regarding FOV, and they will refer to display field of view (dFOV) and camera field of view (cFOV).

dFOV is the user's physical visual field that is covered by the virtual world from the head mounted display. cFOV is the part of the virtual world that is seen by the rendering cameras at any given moment. All FOVs are defined by an angular measurement of vertical, horizontal and diagonal dimensions (Oculus VR, 2015a, p.15).

When it comes to virtual reality, a deviation between dFOV and cFOV have been found unpleasant and can lead to simulation sickness because the screen could look warped. This usually do not affect people when looking at "ordinary screen" displays.
Oculus Rift Configuration Utility can measure the user's dFOV and store these data to be used to recommend a cFOV to match (Oculus VR, 2015a, p.15).

3.3.4 Latency

"Latency is the delay from input into a system to desired outcome" (Rouse, 2014). In relation to Oculus Rift, the latency will be the reaction time from when the computer detects movement from the headset and until it updates the image on the screen according to the movement.

How latency affect the experience

Latency greatly affects the user's experience. In 3D virtual reality simulation, the issue with latency often occurs as lag or delay between the movement detection and the response to it. In the Oculus' *Best Practices Guide* (Oculus VR, 2015a, p. 31) it's encouraged to minimize the latency as much as possible to avoid conflicts in the vestibular system that could lead to simulation sickness.

3.3.5 Vertical synchronization (V-Sync)

The basics about vertical synchronization (v-sync) is that it synchronizes the FPS with the monitor's frame rate. This is an option on the graphics card that prevents the card from changing the display memory until the monitor is done with the refresh cycle. (Jansson, 2015)

For example, a good graphics card may output higher frame rates than the monitor's refresh rate, which might cause tearing of the image. This is often seen in video games. If the monitor's refresh rate is 60Hz, in other words, 60 times a second, and the graphics card outputs 100 FPS, it would cause the two components to be out of sync. If the v-sync option is enabled, the graphics card is told to synchronize with the monitor. (Wawro, 2011)

3.3.6 Timewarp, asynchronous timewarp and judder

Timewarp is a technique that may help reduce the perceived latency in head mounted displays. It warps the rendered image before sending it to the display to help correct head motion that occurred after a scene was rendered. This technique is only applied once per rendered frame and could cause stuttering during head rotation, if the FPS is low (Antonov, 2015). The goal is to reduce 'motion-to-photon' latency, meaning how long it takes from the moment you move your head to when the scene rendered is updated. (Lang, 2014)

Asynchronous timewarp (ATW) is a technique that generates a new timewarped frame from the latest frame completed by the main rendering thread. This means that there are two rendering threads, where the main rendering thread renders as fast as possible to the off-screen memory. The second thread will wait for v-sync and use the latest frame from the main thread before applying timewarp and present the result to the display. (Antonov, 2015; Kuhlen, 2015)

If rendering takes too long and a frame is missed, the representation of a virtual world can result in judder. Judder occurs when the same image is presented to the display a second time. Light falls on a different part of the eye's retina, resulting in judder. This is called double image judder and if the rendered frame is displayed a third time as well, it would cause triple image judder. (Antonov, 2015)

> *"Orientation-only ATW can be used to help address judder: if the rendered game frame is not submitted before vsync, timewarp can interrupt and generate the image instead, by warping the last frame to reflect the head motion since the last frame was rendered. Although this new image will not be exactly correct, it will have been adjusted for head rotation, so displaying it will reduce judder as compared to displaying the original frame again, which is what would have happened without ATW."*
>
> (Michael Antonov, chief software architect at Oculus, about ATW in Virtual Reality)

On a sidenote, it is worth to mention that even though ATW might be a helpful tool, it should not be totally relied upon as there are many challenges to virtual reality technology.

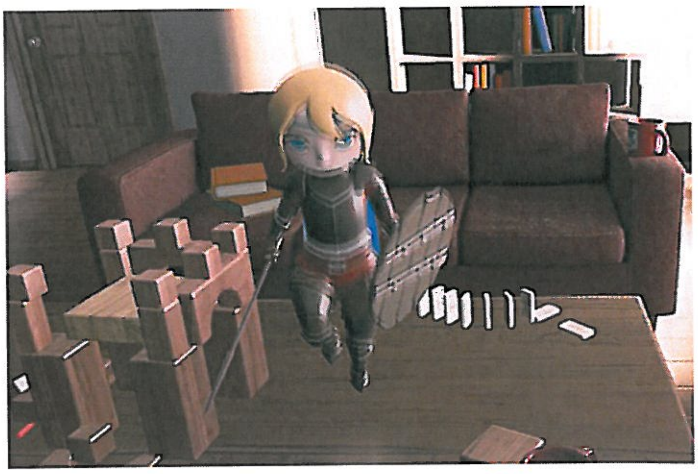

Figure 5: Moving object affected by judder. (Antonov, 2015)

3.4 Oculus Rift Development Kit 2

This kit consist of a headset with cable, positional tracker (camera) with cables, 2 pair of lenses/cups, cloth, HDMI - DVI adapter and power adapters.

Display:

Low Persistency OLED display, later revealed as a Samsung Galaxy Note 3 5.7" AMOLED 1080p screen (iFixit, 2014). This gives a resolution of 960 x 1080 per eye.
Refresh Rate of 75Hz, 72Hz, and 60Hz (Oculus VR, 2015c).

Other features:

100° Field of View.
External camera that tracks the position of the headset, relative to the near-infrared CMOS sensor (60Hz).
Accelerometer, gyroscope, and magnetometer (1000 Hz).
Built-in latency tester to measure system latency.
(Oculus VR, 2015c)

Lenses/cups:

Developer Kit 2 contains two set of lenses; marked A and B, where the A-cup is the pre-installed lenses from the factory. These lenses are designed for people with normal eyesight whilst the B may prove better for nearsighted vision. (Oculus VR, 2014a p. 5)

Requirements:

Minimum requirements: Any computer running one of the following operating systems; Windows 7 or 8, Mac OS 10.8 or higher, Ubuntu 12.04 LTS. 2 USB ports (at least one with power) and a DVI-D or HDMI output.

Recommended requirements: A desktop computer running the minimum requirements, a dedicated graphics card with DVI-D or HDMI output, capable at running current generation of 3D games at 1080p resolution and keep 75 FPS or higher.
(Oculus VR Support, 2015)

Figure 6: The DK2 positional tracker and headset (Oculus VR, 2014b)

Oculus Calibration system

The publicly available Oculus SDK (software development kit) contains a configuration utility where the user can input different measurement settings to optimize the experience.

To help with potential visual issues, the Oculus team created a calibration system where the user can manually set the IPD or use a visual tool. The visual tool is able to adjust eye relief (distance between eye and lens) and IPD values, and can handle asymmetries in eye position. (Oculus VR, 2014a p. 9)
The system also includes a distortion shader, which help the optical distortion adjustments to produce a more correct image on the device. (Oculus VR support, 2014)

As mentioned in section 3.2.2 Interpupillary distance, knowing and adjusting IPD is important to minimize chances of nausea.

3.5 Theory model of our research questions

In figure 7, we have made a theory model that shows the important key words we have to look into and have knowledge about to be able to answer our research questions. These are important parts of our research and visualizes the foundation behind the thesis.

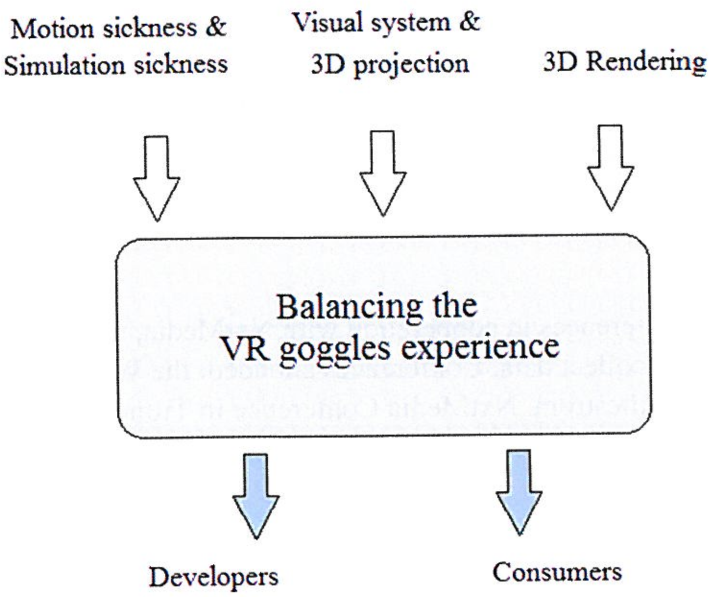

Figure 7: Theory model of our research questions.

3.6 Hypotheses

To be able to answer our research questions we came up with a set of hypotheses that we will look into in our analysis.

- H1: People that have never tried Oculus Rift before have a higher chance to get simulation sickness.
- H2: People in different age groups have a higher chance to get simulation sickness.
- H3: Users in the age group 0-24 are more likely to lose grip of reality while using the Oculus Rift.
- H4: People who easily get sick traveling by car/bus also get simulation sickness.
- H5: People who easily get sick traveling by boat/ferry also get simulation sickness.
- H6: The test group with low FPS on the demo will experience more simulation sickness symptoms than the group with high FPS.
- H7: Women get simulation sickness more often than men.
- H8: People that use technology on a regular basis get less affected by simulation sickness.
- H9: Users with lower or higher IPD than average have a higher chance to get simulation sickness than users with an IPD close to the average.
- H10: Users with lower or higher IPD than average have more problems wearing the Oculus Rift than users with an IPD close to the average.
- H11: Eyesight has an effect on experiencing simulation sickness symptoms when using Oculus Rift.

4 Method chapter

In this chapter, we will explain how we have chosen to collect data for the analysis. We have chosen to work pragmatically in method selection using a quantitative approach, with elements from the qualitative method. In brief, data collection occurred with respondents testing a demo wearing the Oculus Rift DK2 for four minutes, followed by a survey and measurement of the respondent's IPD. The survey has high validity, with questions that point to the theory behind the problem. In addition we have a data collection process with a high degree of reliability. This process have given valuable data to work with in the analysis.

Estimated time used collecting data: Approximately 50 h.

4.1 Respondents

We have attended several conferences in cooperation with NxtMedia, which has given us the opportunity to host a stand to collect data. Conferences attended: the World Publishing Expo in Amsterdam, Spillexpo in Lillestrøm, NxtMedia Conference in Trondheim, Nordic Data Journalism Conference (NODA) in Ålesund and Næringslivsdagen (NLD) at BI Norwegian Business School in Trondheim.

We have a selection of respondents which made use of attendants in the conference that stopped by our stand/booth. The population consists of participants in the various conferences attended and all participants had equal probability to take part in the data collection.

4.2 Operationalization – The survey

The questionnaire used to collect data is designed with nominal and ordinal levels. It is built with a high structured, indirect approach. The questionnaire has fixed answers, grades, and the opportunity to write your own answer if the given options are not adequate for the respondent. It has several Likert indexes where the respondent should express their agreement or disagreement with several statements.

The questionnaire is designed with clear and unambiguous formulations to try to avoid complex terms and phrases. This is done to make sure the survey will be suitable for everyone and not only those with a technical background. We have not mentioned terms like FOV and FPS because we wanted to avoid any confusion for the respondent. Considering how the questionnaire is built, it strengthens the validity of the survey.

The questionnaire exist in English and Norwegian editions and was developed and tested with help from our mentor Knut Ekker and lecturer Trond Olav Skevik before we used it for data collection on conferences.

4.3 Equipment (and tools)

This section contains technical information about the equipment and tools we used to carry out the data collection process as well as information about the scene created for every stand we hosted.

4.3.1 Oculus Rift SDK

The user profile used for testing purposes were set to the default settings but with the 'Eye Relief' adjustment on both headset dial and SDK set to "out", which is the maximum distance. Eye Relief is meant to adjust distance between the surface of the lens and the user's eye. Since the default eye cups are the ones marked "A", these were used in both SDK and on the headset. As the same user profile was used for every participant, it means that we did not use the Oculus' calibration system because we wanted every respondent to have the same foundation for testing.

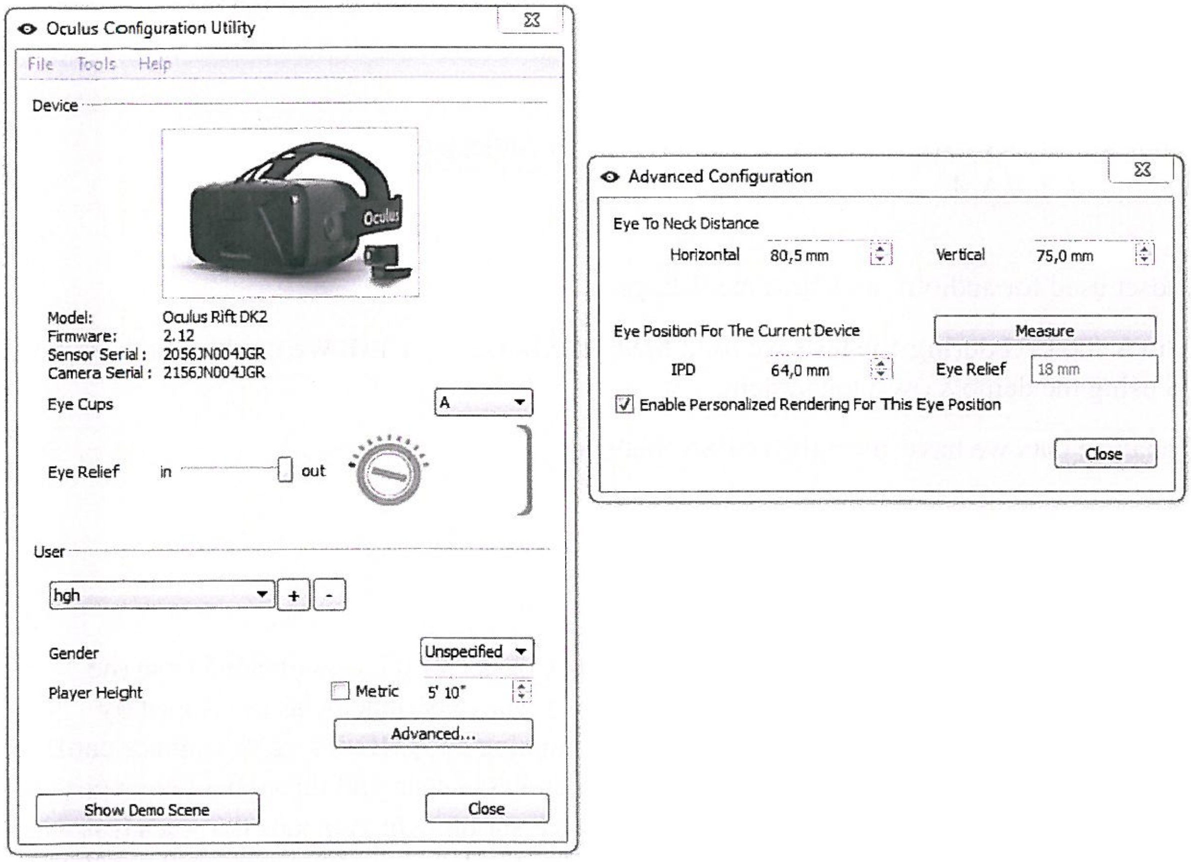

Figure 8: Private screenshot of the settings used. As shown, Oculus VR use the population average IPD of 64mm as default (3.2.2 Interpupillary distance).

Oculus VR Runtime 1.4 rev 1 (SDK version 0.4.2)
Display driver version: 1.0.25.0
Camera driver version: 0.0.1.6

4.3.2 Computers and tools

Main computer specification:

Brand: Dell Precision M6800
OS: Windows 7 Enterprise 64-bit
Processor: Intel Core i7- 4800MQ @ 2,7 GHz
Graphics card: NVIDIA Quadro K3100M – 4 GB dedicated RAM
Memory: 16 GB RAM

At the NxtMedia Conference in Trondheim we had to use another laptop for testing because our main computer was used in another project.

Second notebook specification:

Brand: Asus N56VZ
OS: Windows 7 Home Premium 64-bit
Processor: Intel Core i7-3610QM @ 2.4 GHz
Chipset: Mobile Intel HM76 Express
Graphics card: NVIDIA GeForce GT 650M – 2 GB dedicated RAM
Memory: 8GB RAM

Headset used for audio is an Ultrasone S-Logic.

To track the FPS during the tests we used MSI Afterburner v. 4.1.0. We double checked the FPS using the demo's own log system.

To analyze data we have used IBM SPSS Statistics.

4.3.3 Demonstration experience

The demo we used for testing was Atlantis Infinite Coaster v1.03, downloaded from the Oculus Share webpage (Oculus VR Share, undated). The experience was developed by Sebastian Kuhlen in September 2014 on a device running an AMD R9 x270 graphics card. The demo shows a rollercoaster floating above an endless ocean and through a fictive city. The tracks and the city is generated randomly at each startup which means that each test will have a slight variation in layout (Kuhlen, 2014). The developer used his own implementation of asynchronous timewarp (3.3.6 Timewarp, asynchronous timewarp and judder; Kuhlen, 2015) to help reduce latency. The demo was developed towards the movement experience rather than visual expression.

As the experience is infinite, we chose to limit the test to four minutes per respondent.

4.3.4 IPD Measurement

Additionally we want to measure the IPD on the respondents. At first, we took a picture of the respondent's eyes with a pen under their eyes as measurement scale. The thought was that we later on could measure the approximated IPD using Photoshop.

Figure 9: The pen to the left would be used as a scale to measure IPD. In this case, the IPD could be measured correctly.

Figure 10: The pen or camera disturbed the respondent's eyes and the measurement of IPD would be incorrect.

After a conversation with optometrist Richard Nilsen (Nilsen, 2015) at Synsam Steinkjer Synssenter, we changed the method used to measure IPD. He gave us more information about IPD measurement and he showed us a new technique; using a ruler. See figure 11. This technique is more reliable than our first method, shown in figure 9 and 10. We measured the IPD standing one arm length away from the respondent in front of them and told them to focus on a point between the measurers eyes. We held the ruler above their eyes and approximately measured the distance between their pupils.

Figure 11: Illustration of how to measure IPD with a ruler.

4.4 The scene

At each test/conference/something we had a table for the computer and a chair for the respondent. The positional tracker was mounted on top of the laptop screen, which was placed in front of the respondent.

The respondents were informed briefly about the Oculus Rift and how the positional tracker works. This was done to strengthen the reliability because we made sure the respondents were aware of the possibilities for movement.

We put the Oculus Rift goggles on the respondent's head and made sure that it was fitted comfortably before we started the demo experience. As the demo started, the respondent was also fitted with a headset to be able to receive audio.

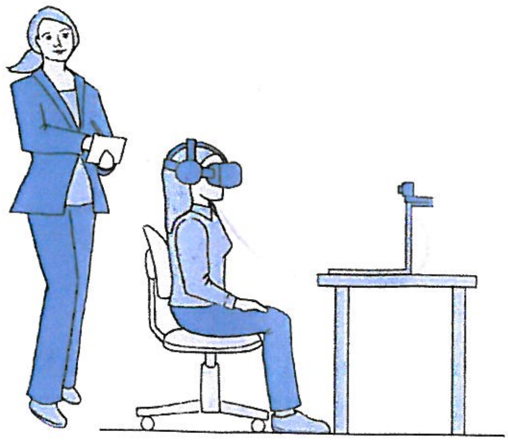

Figure 12: Illustration of how the scene is staged. The respondent is sitting and we are observing (Illustration made by S. Bendiksen).

4.5 Qualitative observation

When collecting data, we observe the respondent for physical reactions while they test the demo. This is a direct approach with a planned observation. We wrote down notes regarding the respondent's body language, studied how they were seated and looked for change in breathing pattern. We observed if their balance were effected, and if they lost their balance in any way. We also take notes on their body movement, if they use their head to look around, using their whole upper body or if they didn't move at all. Lastly we also take notes on their verbal behavior.

We were both always present during collection of data, which means that we have kept the response rate high and decreased the possibility of misunderstandings. In other words, this approach strengthens the reliability of our qualitative observation.

4.6 Measurement errors

To reduce measurement errors we have had guidance from our mentor and tutor when it comes to the design of the questionnaire. We have focused on asking the right questions in order to reach the relevant data.

We have had a structured approach when it comes to direct and indirect measurement of behavior, as we have designed a questionnaire with fixed response alternatives and had a planned observation when respondents tested Oculus Rift.

Measurement errors when collecting data

Factors that can have an influence on the collected data is the environmental conditions. Could background noise, the traffic of people walking by or a possible audience at the stand be a distraction and affect the respondent's experience?

When collecting data we have to be prepared for the possibility of measurement errors regarding the respondent's reactions. As we have no way of knowing/proving if the reactions are in fact realistic, we have to be aware that they may be a Hawthorne effect (the respondent know they are being observed, either by us, friends or anyone else around the booth) or a reaction to the fascination of the technology rather than the experience itself.

> *"The Hawthorne effect is a term referring to the tendency of some people to work harder and perform better when they are participants in an experiment. Individuals may change their behavior due to the attention they are receiving from researchers rather than because of any manipulation of independent variables."*
>
> (Cherry, Psychology Expert, undated)

There is also a possibility that the answers regarding eyesight will contain errors that might influence the end analysis. People may not remember or know if they are near- or farsighted or if they have other conditions than reduced vision.

Lastly, some of the respondents may receive help from family or friends when answering the questionnaire, which might influence their answers. This is not necessarily a measurement error but it's still something we have to be aware of.

5 Analysis chapter

The analysis chapter consists of the results found in the collected data; both from the questionnaire and observations. First background information about the population list is presented before moving on to analyzing relations between different variables. We will also see if we can confirm or discard the hypotheses.

See the questionnaire (attachment 3) and measures of association (attachment 4) for a better understanding of the analysis chapter.

5.1 Population background information

In total this analysis had 187 participants, where 145 were men and 42 women, see figure 13. This leaves us with a percentage of 77,5 % men and 22,5 % women. The questionnaire had an "other" category but no one used this option.
The population list have participants in different age groups, results presented in figure 14 and percentage in Figure 15.

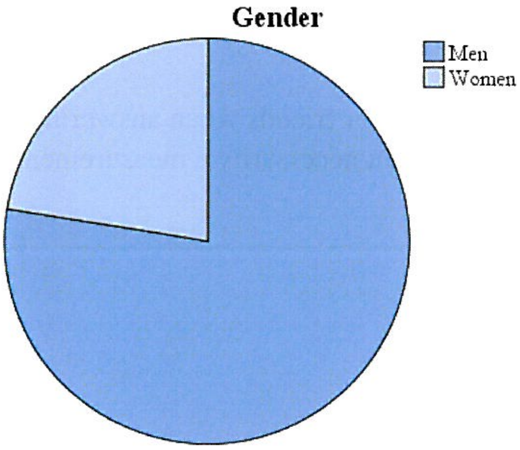

Figure 13: Divided by gender

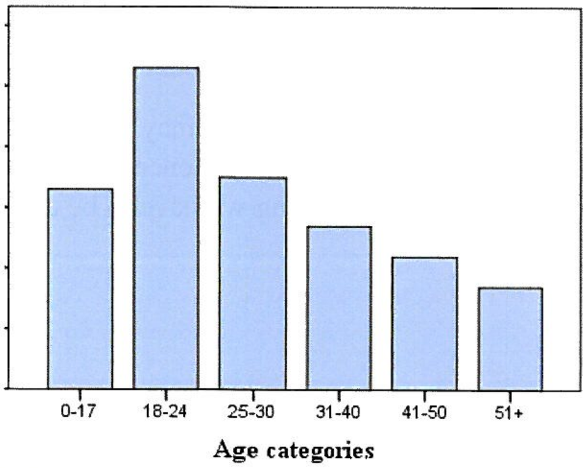

Figure 14: Participants divided in age groups

Age categories	Frequency	Percentage
0-17	33	17,6%
18-24	53	28,3%
25-30	35	18,7%
31-40	27	14,4%
41-50	22	11,8%
51 +	17	9,1%

Figure 15: Participants divided in age groups shown in frequency and percentage

One of the questions focusing on the participant's background was regarding education. In the population there are 184 given answers, here presented in percentage. See figure 16 and figure 17.

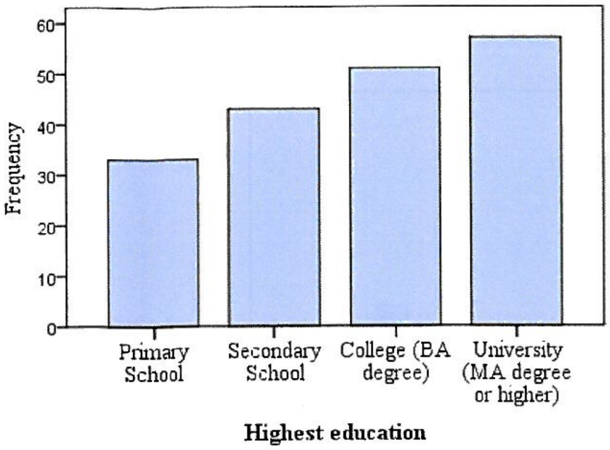

Figure 16: Participants divided by highest education

Highest education	Frequency	Percent
Primary School	33	17,9%
Secondary School	43	23,4%
College	51	27,7%
University	57	31,0%
Total	184	100%

Figure 17: Participants divided by highest education in frequency and percentage

Eyesight

Data shows that 50,6 % of the population has normal eyesight, whereas 33,3% are nearsighted and 14,4% are farsighted. Lastly 1,7 % of the population are both near - and farsighted. In total 180 participants chose to provide an answer. See figure 18.

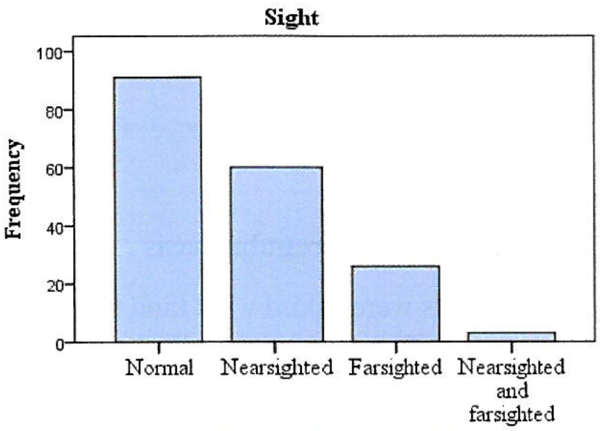

Figure 18: Participants divided by eyesight

Vision correction

185 participants have answered whether they use glasses or contact lenses. 25,9 % said they use glasses and 17,3 % said they use contact lenses. See figure 19.

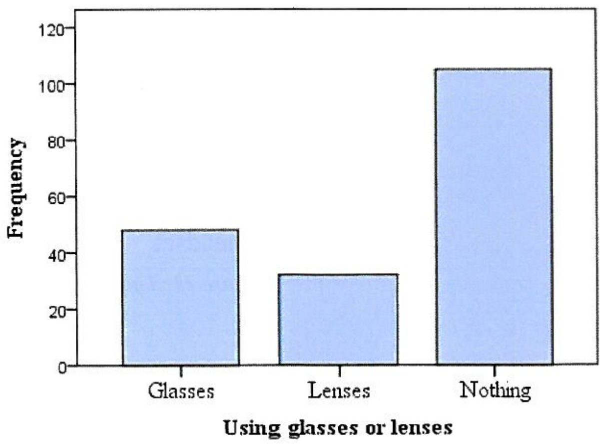

Figure 19: Participants divided by lenses and glasses

IPD

IPD measurement was collected from 56 participants. We do not have a full participant group for this collection due to the fact that we had to change our method for IPD measurement (see 4.3 – IPD measurement). The mean of the data is 61,77mm which is below the average population IPD of 64mm. See figure 20.

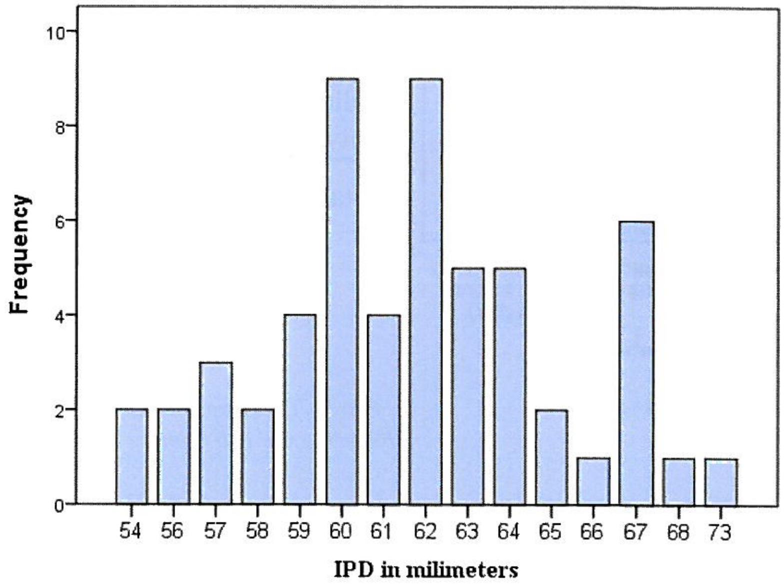

Figure 20: Participants divided by their IPD.

Technology used on a regular basis

The participants were asked what kind of technology they use on a regular basis during the last two weeks. This was a multiple choice question. See figure 21.

Technology	Percentage
Smartphones	96,3%
PC/mac	91,4%
Tablet/iPad	54,4%
Video game console	36,4%
Handheld video game console	8,6%
Virtual Reality headset	5,3%

Figure 21: The usage of different technology devices

Tried VR before

The respondents were asked if they have tried the Oculus Rift or other Virtual Reality headsets before, which was a multiple choice question. 175 participants have given one or multiple answers. See figure 22.

The answers showed that 72,6 % of the respondents have never tried Virtual Reality goggles before. 27,4% have tried Oculus Rift and/or other Virtual Reality goggles.

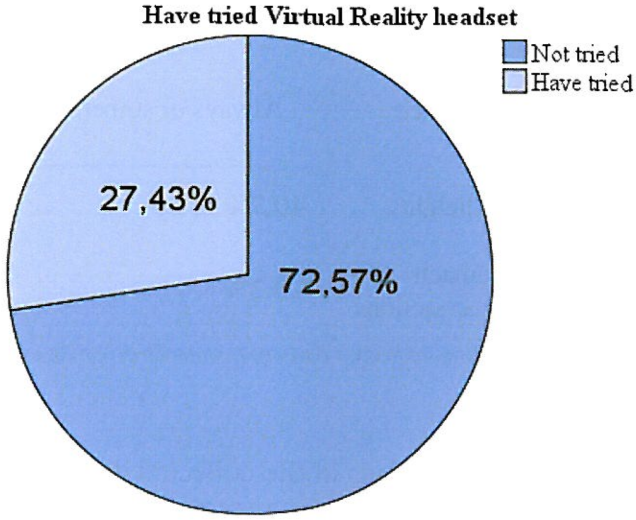

Figure 22: Participants divided by if they have experienced the Oculus Rift before or not

Motion sickness

Figure 23 gives a clear understanding whether the respondents usually get the feeling of nausea or sickness when going through specific experiences. In the questionnaire "always or sometimes" and "rarely or never" are four separate answers but we chose to merge these alternatives because it's easier to analyze the given data and detect patterns in the responses. Frequency is the number of respondents that chose to answer.

As seen from the results in figure 23, traveling by car/bus and traveling by boat/ferry is the most common experiences that can cause motion sickness.

Motion Sickness

	Always or sometimes	Neutral	Rarely or never	Frequency
Traveling by car or bus	22,7%	3,8 %	**73,5%**	185
Traveling by train	4,4%	3,8%	**91,8%**	183
Traveling by airplane	4,9%	2,7%	**92,4%**	184
Traveling by boat/ferry	22,4%	6,0%	**71,6%**	183
When playing video games	2,5%	1,3%	**96,2%**	157

Figure 23: Motion sickness.

We also asked whether the participants are afraid of heights and if they enjoy rollercoasters and/or other "stomach dropping" attractions. See figure 24. It's important that these questions were asked because the given answers can contribute to the study of the effect of motion sickness and physical emotions.

Other factors				
Experience	Always or sometimes	Neutral	Rarely or never	Frequency
Afraid of heights	40,7%	12,1%	**47,3%**	182
Enjoy stomach dropping attractions	**70,2%**	11,0%	18,8%	181

Figure 24: Afraid of heights and enjoy stomach dropping attractions, including rollercoasters

5.1.1 Other findings in the collected data of the population

After at the data about the respondents had been analyzed, other connections between different variables were noticed. These findings are not necessarily connected to the research questions, but the results are interesting and *could* possibly have an effect.

Sight and age

Figure 25 shows age compared with eyesight (Attachment 5, section 1.1). The independent variable is age and the dependent variable is sight. We use Cramer's V for symmetric measures because we are using more than two values. Cramer's V value is 0,329 and p = 0,00 we can conclude that there is a strong connection between age and eyesight. It is more common to have normal eyesight with younger age.

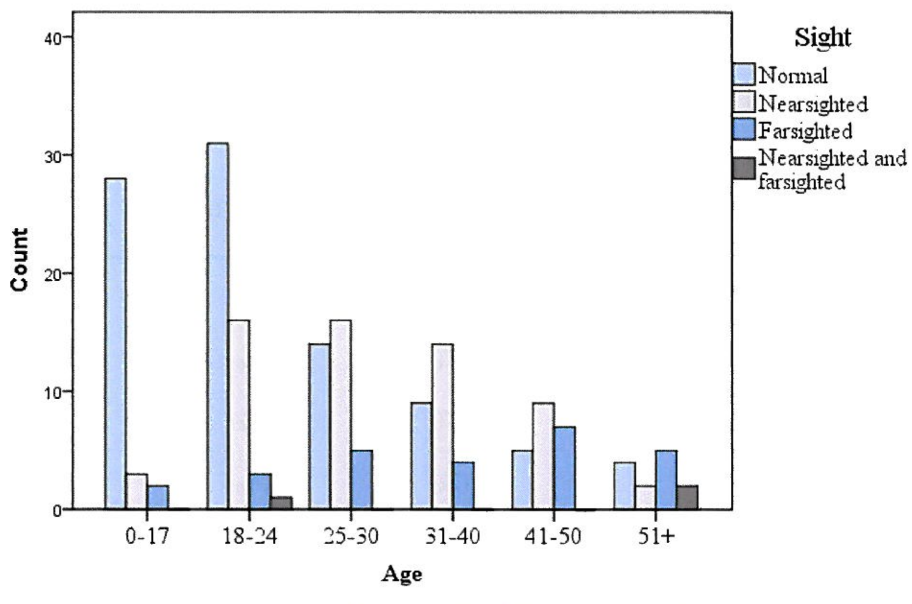

Figure 25: The connection between age and vision.

Afraid of heights and enjoying rollercoasters

The results in figure 26, show that even though a lot of the respondents seem to be afraid of heights, the percentage of respondents enjoying stomach dropping attractions is still high.

The Cramer's V value is 0,227 and p < 0,05 (attachment 5, section 1.2) we can conclude that there is a moderate connection between being afraid of heights and enjoying stomach dropping attractions.

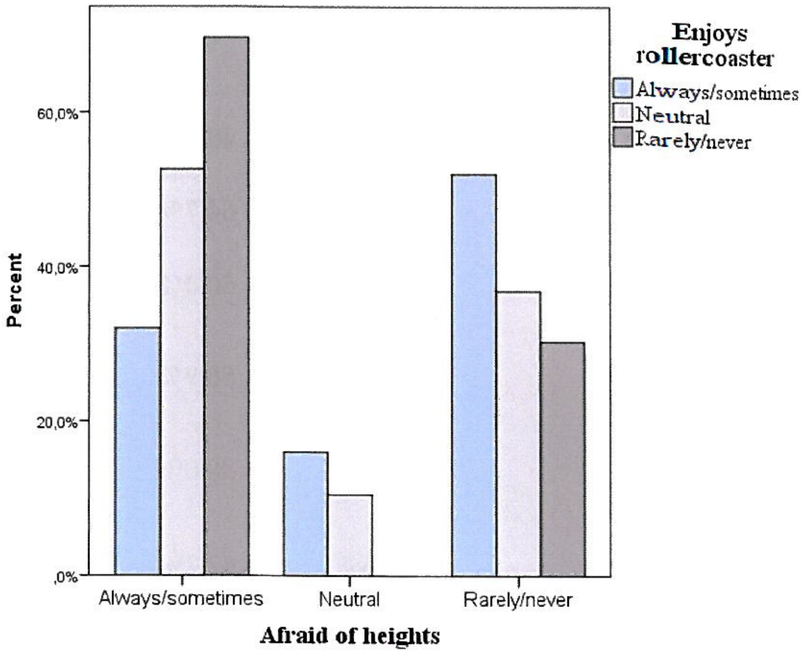

Figure 26: Connection between enjoying rollercoasters and being afraid of heights

This result made way for another analysis. 40% of the respondents who answered "always/sometimes" to "I am afraid of heights" and "I enjoy rollercoasters" felt a stomach drop during the experience with Oculus Rift and 90% answered that it was a fun experience testing it. See attachment 5, section 1.3 and 1.4.

5.2 After the experience

This part of the questionnaire was filled out after the participants had tested the demo and been checked for IPD measurement. See figure 27 and figure 28. In the questionnaire "I agree or partly agree" and "I partly disagree or disagree" are four separate answers but these alternatives were merged because it's easier to analyze the given data and detect any patterns in the responses.

After experience emotions

	I agree or partly agree	I am neutral	I partly disagree or disagree	Frequency
Felt dizzy easily	38,8%	12,6%	**48,6%**	183
Felt nauseous	23,4%	12,0%	**64,7%**	184
Lost balance	37,5%	12,5%	**50,0%**	184
Felt disoriented	26,1%	15,0%	**58,9%**	180
Got an adrenaline rush	**43,5%**	18,5%	38,0%	184
Got a "stomach drop"	**43,2%**	14,6%	42,2%	185
Lost grip of reality	30,2%	15,4%	**54,4%**	182
Felt scared	8,2%	9,8%	**82,1%**	184
Felt insecure	13,5%	11,4%	**75,1%**	185
Lost control	20,5%	10,8%	**68,6%**	185
Afraid to get hurt	4,3%	3,2%	**92,4%**	185

Figure 27: Results after the experience

After experience emotions	I agree or partly agree	I am neutral	I partly disagree or disagree	Frequency
Fun experience	**89,8%**	7,5%	2,7%	186
Felt excited	**79,0%**	13,4%	7,5%	186
Felt surprised	**70,3%**	15,1%	14,6%	185
Felt bored	11,3%	11,3%	**77,4%**	186
Felt emotionally moved	28,2%	19,3%	**52,5%**	181
Picture quality was satisfying	28,1%	18,4%	**53,5%**	185
The colors used were not bothering	**62,9%**	19,9%	17,2%	186
The lighting used were not bothering	**67,7%**	22,6%	9,7%	186

Figure 28: Results after the experience

The respondents were asked if they would like to try the Oculus Rift again, and/or other Virtual Reality headsets. 89,1 % agreed or partly agreed to try the Oculus Rift again and 93,5% agreed or partly agreed to be willing to try other virtual reality headsets.

Feeling of unwellness

This question regards what the respondents did if they felt sick or nauseous during the test, and was a multiple choice question. See figure 29. 54% of the respondents answered that they did not feel sick or nauseous.

Solutions	Percentage
Tried focus ahead	15,5%
Tried to orientate to the surroundings	20,3%
Took the headset off	0,5%
Nothing	9,1%
Other	6,1%

Figure 29: Solutions from the respondents if they felt sick or nauseous during or after the demo.

The "other" option had a comment field where the respondents could explain what they did to stop the feeling of unwellness. The frequency of "other" is 12, and 2 of these claimed they did not feel nauseous but felt a discomfort. 4 participants closed their eyes, 3 participants held on to the chair or thought about the chair or headset (to focus on reality), the remaining participants either looked down, tried to keep their body still or claimed they wanted to wash their face with water.

Discomfort with the Oculus Rift headset or the attached lenses

The respondents were asked if they felt any discomfort using the Oculus Rift DK2 headset. This was a multiple choice question. As the results shows in figure 30, the majority of the respondents, 80,2 %, did not have any discomfort or problems it.

Problems with headset/lenses	Percentage
Yes, the lenses bothered me a bit	6,4%
Yes, I was bothered because I normally wear glasses	6,4%
Yes, the headset was uncomfortable	4,3%
No, it was fine	80,2%

Figure 30: Results regarding comfort wearing the Oculus Rift DK2 headset

Population list opinions regarding unwellness/nausea

This question was a multiple choice question where the respondents were what they think could cause the feeling of unwellness or nausea while using the Oculus Rift. As figure 31 shows, the respondents believe the sensation of moving is the most common reason followed by quick movement for the eye.

Possible causes for unwellness	Percentage
High-Contrast Colors / Color experience	8,6%
Lighting	3,7%
Quick movement for the eye	31,0%
Sensation of moving	62,0%
Other	10,8%

Figure 31: Possible causes for unwellness

The majority of the respondents that chose to comment on the "other" section suggests that low framerate and low resolution/image quality as well as mismatch between expected and experienced movement can cause unwellness when using the Oculus Rift.

5.3 FPS measurement

When the project first started, the first part of the respondents were testing the demo with the quality settings set to "high". The measurements showed that the values varied between 21-30 FPS during the 4 minute experience, but that values between 22-25 FPS were the most frequent.

Later in the project the last respondent group tested with the quality settings to "very low". The MSI Afterburner (5.3.2 Computers and tools) showed that the values were between 43-67 FPS, with values between 50-55 FPS as the most frequent.
As mentioned in chapter 3.3.1 Frame rate (FPS) the brain needs at least 15 FPS to believe that what it sees is actually moving (Clarkson, 2009).

The FPS results were cross checked with the demo's own logging system (a text file that could be set to log different events in the demo) and the developer also confirmed that the MSI Afterburner seems to measure the correct FPS. We had to make sure that the FPS measurements were correct because of the way the demo uses asynchronous timewarp, which could lead to different measurements between what is actually rendered and what is presented to the user.

5.4 Testing Hypotheses

This chapter covers testing the hypotheses using the collected data. When the term 'simulation sickness' (3.1.3 Simulation sickness) is used in a hypothesis, the variables from question 8.1, 8.2 and 8.3 in the questionnaire (attachment 3) are used because these variables are symptoms. The term 'motion sickness' (3.1.2 Motion sickness) should not be confused with simulation sickness. See attachment 5 for the data sources.

5.4.1 No previous experience with Oculus Rift and simulation sickness

H1: "People that have never tried Oculus Rift before have a higher chance to get simulation sickness."

To put this hypothesis to the test, the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the respondents that have no previous experience with the Oculus Rift (question 6).

Experiencing dizziness

The results in the cross tabulation in figure 32 shows that there is no connection between not having tried the Oculus Rift before and dizziness. The Cramer's V value is 0,134 (p =0,20) which shows a very weak connection and therefore we can conclude that there is no relationship between these variables.

	8.1 I felt dizzy easily			Total %	Frequency
	Agree / partly agree	Neutral	Partly disagree / disagree		
Have tried Oculus Rift before	29,3%	13,8%	56,9%	100%	58
Have not tried Oculus Rift before	43,2%	12,0%	44,8%	100%	125

Figure 32: Connection between earlier experience with Oculus Rift and feeling dizzy during/after the demo

Experiencing nausea

The results in figure 33 shows that there is no connection between not having tried the Oculus Rift before and nausea. The Cramer's V value is 0,106 (p = 0,35) which shows a very weak connection and therefore we can conclude that there is no relationship between these variables.

	8.2 I felt nauseous			Total	Frequency
	Agree / partly agree	Neutral	Partly disagree / disagree		
Have tried Oculus Rift before	24,1%	6,9%	69,0%	100%	58
Have not tried Oculus Rift before	23,0%	14,3%	62,7%	100%	126

Figure 33: Connection between earlier experience with Oculus Rift and feeling nausea during/after the demo

Sense of balance

The results in the cross tabulation in figure 34 shows that there is no connection between not having tried the Oculus Rift before and balance. The Cramer's V value is 0,098 (p = 0,41) which shows a very weak connection and therefore we can conclude that there is no relationship between these variables.

	8.3 I lost my balance			Total	Frequency
	Agree / partly agree	Neutral	Partly disagree / disagree		
Have tried Oculus Rift before	34,5%	17,2%	48,2%	100%	58
Have not tried Oculus Rift before	38,9%	10,3%	50,8%	100%	126

Figure 34: Connection between earlier experience with Oculus Rift and sense of balance during/after the demo

Conclusion

Since the Cramer's V value is very weak and p > 0,05 in all three cross tabulations, we can conclude that there is no connection between having previous experience with the Oculus Rift and simulation sickness. Therefore we discard hypothesis H1.

5.4.2 Different age groups and simulation sickness

H2: "People in different age groups have a higher chance to get simulation sickness."

To put this hypothesis to the test, the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the different age groups, question 2. See attachment 5, section 2.

Experiencing dizziness

The results in figure 35 shows that there is a moderate connection between age groups and to become dizzy. The Cramer's V value is 0,202 (p = 0,06) and therefore we can conclude that there is a relationship between these variables.

We see that the age group 0-24 has a significantly less chance to experience dizziness while the age group 31-40 has a higher chance.

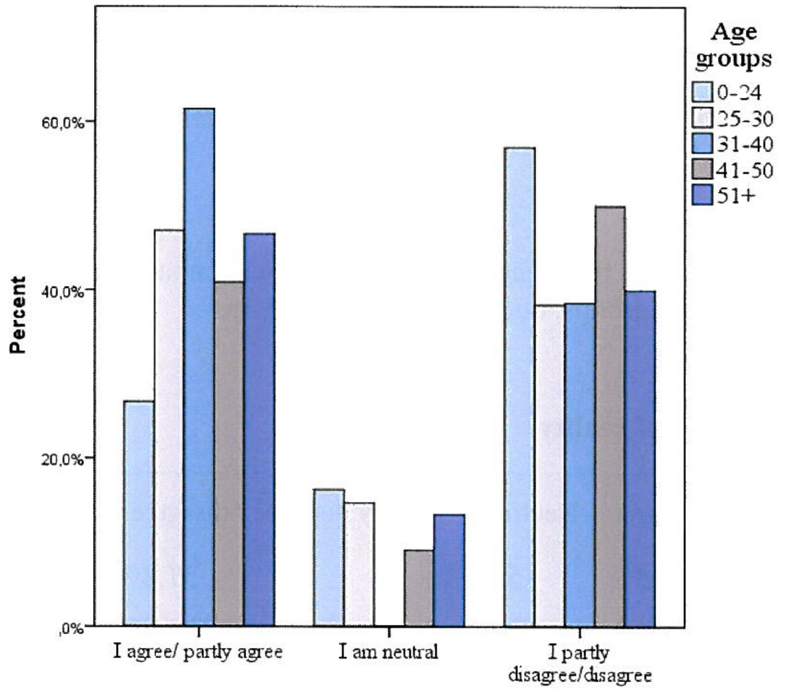

Figure 35: Connection between age and feeling dizzy during/after the demo

Experiencing nausea

The results show that there is a very weak connection between age and to become nauseous. The Cramer's V value is 0,128 (p = 0,64) and therefore we can conclude that there is no relationship between these variables.

We can also see that the age group 31-40 are more exposed to experience nausea even though the connection is weak.

Sense of balance

The results show that there is a very weak connection between age and losing balance. The Cramer's V value is 0,131 (p = 0,61) and therefore we can conclude that there is no relationship between these variables.

Conclusion

Since the Cramer's V value is very weak when it comes to nausea and balance and p > 0,05 in all three cross tabulations, we can conclude that there is no connection between age and simulation sickness. Therefore we discard hypothesis H2.

However, even if the numbers are not strong enough to keep H2, the age group 0-24 has a smaller chance to experience dizziness than the other age groups (see figure 35).

5.4.3 Age group 0-24 and losing grip of reality

H3: "Users in the age group 0-24 are more likely to lose grip of reality while using the Oculus Rift."

To test this hypothesis the answers from question 8.7 in the questionnaire were analyzed and compared with the different age groups, question 2. See figure 36.

		8.7 Lost grip of reality			**Total**	**N**
		Agree / partly agree	Neutral	Partly disagree / disagree		
Age	0-24	32,5%	15,7%	51,8%	100%	83
	25-30	23,5%	17,6%	58,8%	100%	34
	31-40	**48,1%**	7,4%	44,4%	100%	27
	41-50	18,2%	18,2%	63,6%	100%	22
	51+	18,8%	18,8%	62,5%	100%	16

Figure 36: Connection between age and losing grip of reality.

Conclusion

The Cramer's V value is 0,148) (p = 0,43) and there is a weak connection between age and experiencing losing grip of reality. The age group 31-40 is more likely to lose grip of reality than the other age groups. Therefore we discard H3.

5.4.4 Motion sickness by car/bus and simulation sickness

H4: "People who easily get sick traveling by car/bus also get simulation sickness."

To test this hypothesis the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the answers from question 7.1. See attachment 5, section 4.

Experiencing dizziness

The results show that there is a moderate connection between easily getting sick by car/bus and experience dizziness with Oculus Rift. The Cramer's V value is 0,191 (p= 0, 01) and therefore we can conclude that there is a relationship between these variables. See figure 37.

57,1% of the respondents said that they often experienced motion sickness traveling by car/bus and felt dizziness with the Oculus Rift.

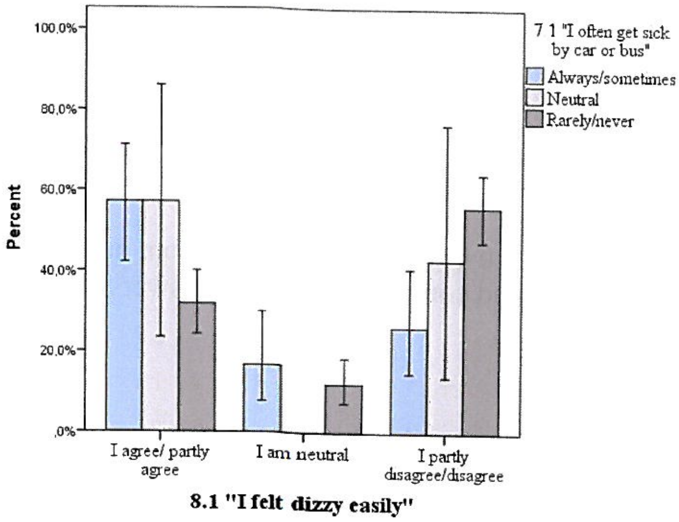

Figure 37: Connection between motion sickness by car and feeling dizzy with Oculus Rift.

Experiencing nausea

The results show that there is a moderate connection between easily getting sick by car/bus and experience nausea with Oculus Rift. The Cramer's V value is 0,222 (p = 0,001) and therefore we can conclude that there is a relationship between these variables. See figure 38.

35, 7% of the respondents said that they often experienced motion sickness traveling by car/bus and felt nauseated with the Oculus Rift.

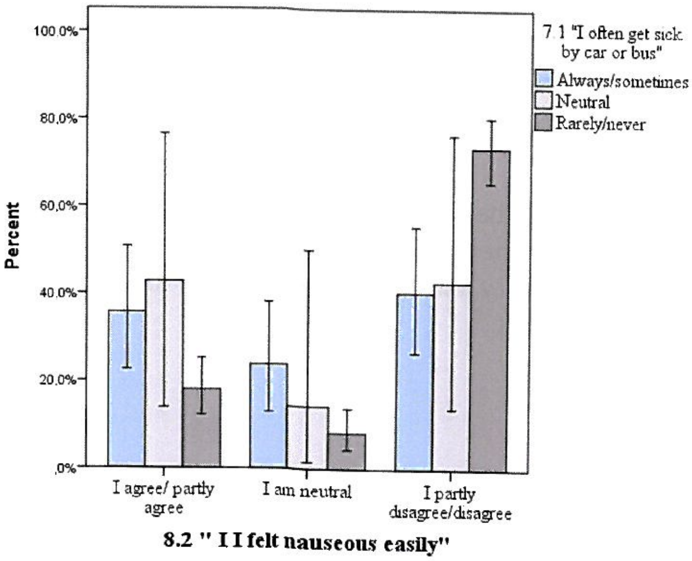

Figure 38: Connection between motion sickness by car and experiencing nausea with Oculus Rift.

Sense of balance

The results show that there is a very weak connection between easily getting sick by car/bus and losing balance with Oculus Rift. The Cramer's V value is 0,136 (p = 0,15) and therefore we can conclude that there is no relationship between these variables.

Conclusion

As we can see, it's a higher chance to experience dizziness and nausea if the user is prone to get sick traveling by car/bus. *Even though we can conclude that there is no relationship when it comes to losing balance with the Oculus Rift and motion sickness, we want to keep H4 because of the moderate connection between motion sickness and experiencing dizziness and nausea.*

5.4.5 Motion sickness by boat/ferry and simulation sickness

H5: "People who easily get sick traveling by boat/ferry also experience simulation sickness."

To test this hypothesis the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the answers from question 7.4. See attachment 5, section 5 for source data.

Experiencing dizziness

The results show that there is a moderate connection between easily getting sick by boat/ferry and experience dizziness with Oculus Rift. The Cramer's V value is 0,228 (p= 0,001) and therefore we can conclude that there is a relationship between these variables. See figure 39.

53, 7% of the respondents said that they often experienced motion sickness traveling by boat/ferry and felt dizziness with the Oculus Rift.

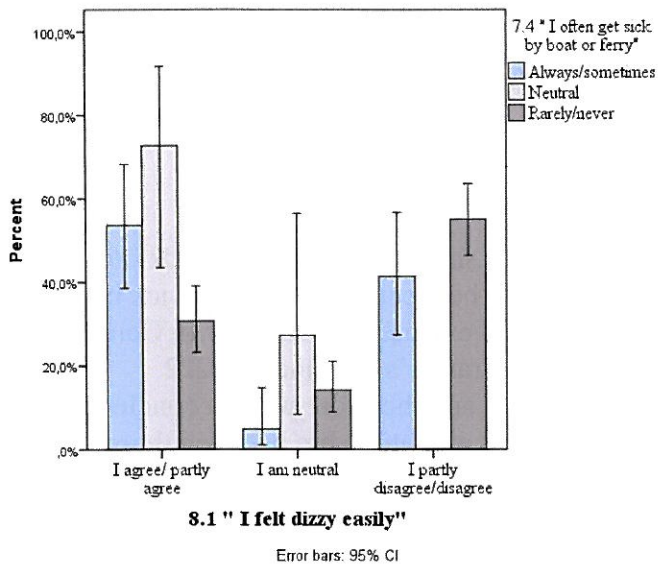

Figure 39. The connection between motion sickness by boat or ferry and feeling dizzy with Oculus Rift.

Experiencing nausea

The results show that there is a moderately strong connection between easily getting sick by boat/ferry and experience nausea with Oculus Rift._The Cramer's V value is 0,285 (p = 0, 00) and therefore we can conclude that there is a good relationship between these variables. See figure 40.

41, 5% of the respondents said that they often experienced motion sickness traveling by boat/ferry and felt nauseated with the Oculus Rift.

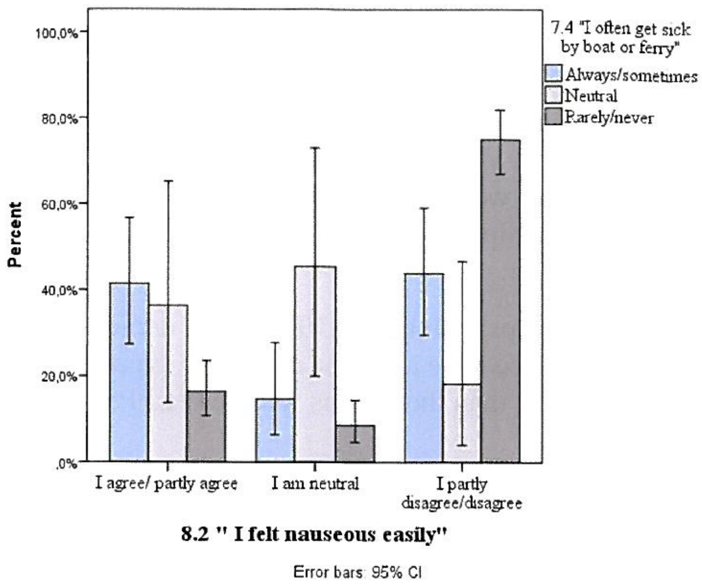

Figure 40: The connection between motion sickness by boat or ferry and feeling nausea with Oculus Rift.

Sense of balance

The results show that there is a very weak connection between easily getting sick by boat/ferry and losing balance with Oculus Rift. The Cramer's V value is 0,088 (p = 0, 59) and therefore we can conclude that there is no relationship between these variables.

Conclusion

As we can see, it's a higher chance to experience dizziness and nausea if the user is prone to get sick traveling by boat/ferry. Even though we can conclude that there is no relationship when it comes to losing balance with the Oculus Rift and motion sickness, we want to keep H5 because of the moderate/moderately strong connections between motion sickness and experiencing dizziness and nausea.

5.4.6 FPS and simulation sickness

H6: "The test group with low FPS on the demo will experience more simulation sickness symptoms than the group with high FPS."

To test this hypothesis the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared to the "high" and "low" FPS groups. See section 5.3 FPS measurement and attachment 5, section 6.

Experiencing dizziness

The results show that there is a moderate connection between FPS and dizziness. The Cramer's V value is 0,233 (p = 0,007) and therefore we can conclude that there is a relationship between these variables. See figure 41.

The groups with higher FPS on the demo experience have a higher chance to experience dizziness than the groups with lower FPS.

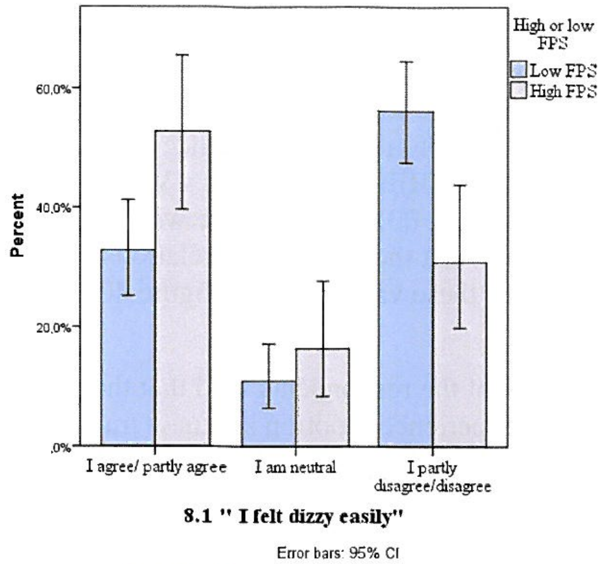

Figure 41: The connection between low or high FPS and feeling dizzy with Oculus Rift.

Experiencing nausea

The results show that there is a moderate connection between FPS and nausea. The Cramer's V value is 0,238 (p = 0,005) and therefore we can conclude that there is a relationship between these variables. See figure 42.

The groups with higher FPS have a higher chance to experience nausea than the groups with lower FPS.

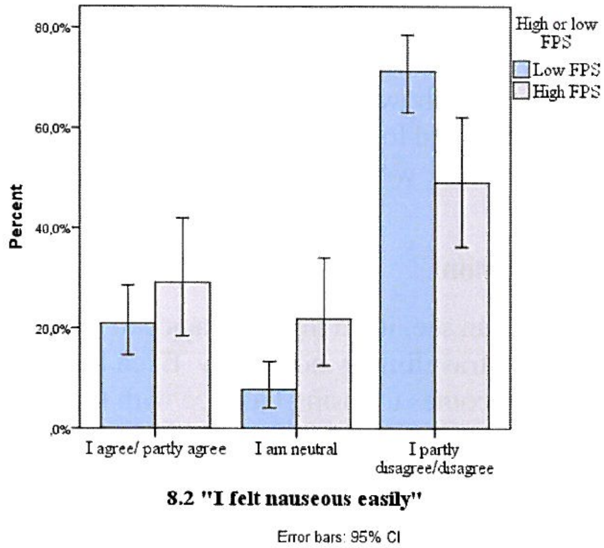

Figure 42: The connection between low or high FPS and experience nausea with Oculus Rift.

Sense of balance

The results show that there is a moderate connection between FPS and balance.
The Cramer's V value is 0, 23 (p = 0,008) and therefore we can conclude there is a relationship between these variables.
See figure 43.

The group with higher FPS have a higher chance to experience balance issues than the group with low FPS.

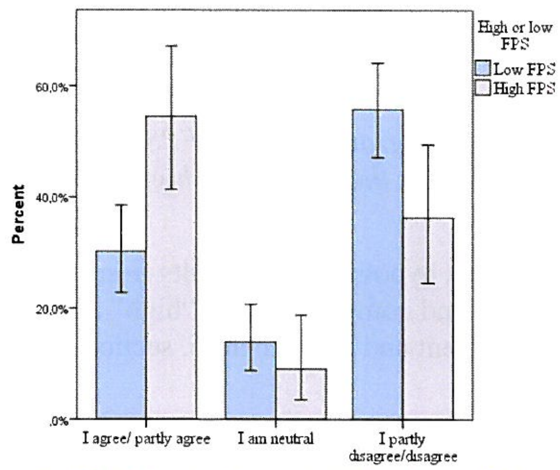

Figure 43: The connection between low or high FPS and losing balance.

Conclusion

Since the Cramer's V value is moderate on all three variables, and p = 0,005 when it comes to nausea and p < 0,01 when it comes to dizziness and sense of balance, we can conclude that there is a connection between low/high FPS and simulation sickness.

However, these results do not mean that the experience get more pleasant with low FPS but a high FPS count may give more realistic feelings. We discard H6 based on this outcome because the result shows the opposite of the hypothesis.

Considering these results, a closer look at the FPS groups, and the answers given on other "after experience" variables, seemed interesting. The answers from questions 8.6, 8.7, 9.1 and 9.8 were used for this analysis.

Follow up questions and discussion

"Does the group with low FPS experience the picture quality as more satisfying than the group with high FPS?"

See attachment 5, section 6.4, regarding question 9.8 "The picture quality was satisfying".

52,7 % of the participants in the group "low FPS" answered that they partly disagreed or disagreed. 55.4 % in the group "high FPS" also partly disagreed or disagreed

The result shows that there is a very weak connection between these variables. The Cramer's V value is 0,079 (p = 0,57). This means that there is no relationship between high or low FPS and the picture quality. In other words, the participants agreed to the level of graphical quality, regardless of FPS.

"Will the group with high FPS have a higher chance to experience a stomach drop?"

There is a moderate connection between FPS and question 8.6 "I got a stomach drop". The Cramer's V value is 0,237 (p = 0,005) which means there is a relationship between these variables. See figure 44.
With a high FPS there is a higher chance to feel a stomach drop.

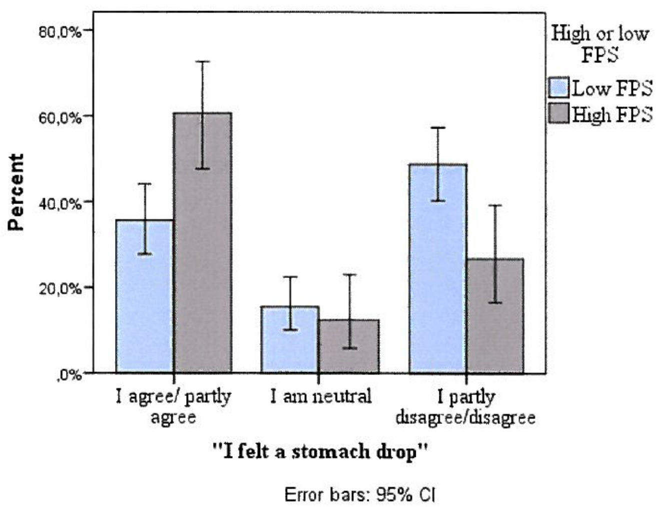

Figure 44: The connection between low or high FPS and experiencing a stomach drop with Oculus Rift.

"Will the group with high FPS have a higher chance to experience that they lose grip of reality?"

There is a weak connection between FPS and question 8.7 "I lost grip of reality". The Cramer's V value is 0,178 (p = 0,055) which means there is a weak relationship between these variables because Cramer's V is minimally acceptable and p > 0,05. See figure 45.

There's a higher chance to lose grip of reality with a high FPS count. (High: 39,3%, low: 26,2% experienced that they lost grip of reality)

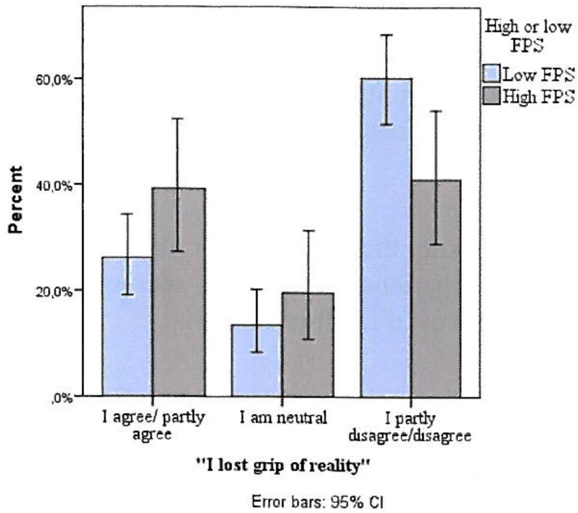

Figure 45: The connection between low or high FPS and losing grip of reality with Oculus Rift.

"Does the group with high FPS have a more fun experience than the group with low FPS?"

There is a very weak connection between FPS and question 9.1 "It was a fun experience". The Cramer's V value is 0,038 (p = 0,872) which means that there is no relationship between these variables. See figure 46.

89, 2 % within the group low FPS and 91, 1% within the group high FPS agreed or partly agreed that it was a fun experience.

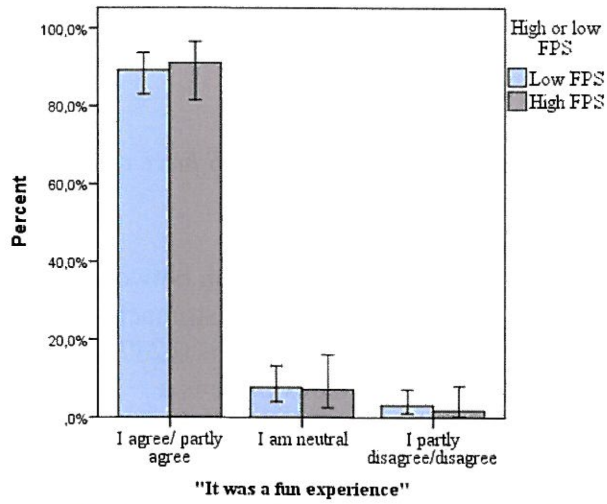

Figure 46: The connection between low or high FPS and having a fun experience with Oculus Rift.

Conclusion

If we look at all the results from testing FPS, high FPS will give more physical reactions. However, this does not mean that FPS is the main reason for any unpleasantness during the test.

5.4.7 Gender and simulation sickness

H7: "Women get simulation sickness more often than men".

To test this hypothesis the results from question 8.1, 8.2 and 8.3 in the questionnaire have been analyzed and been compared with question 1, gender.
See attachment 5, section 7.

Experiencing dizziness

The results show there is a very weak connection between gender and dizziness. The Cramer's V value is 0,143 (p = 0,15) therefore we can conclude that there is no relationship between these variables. Women have a slightly higher chance to get dizzy but the difference between genders are not generally acceptable.

Experiencing nausea

The results show that there is a very weak connection between gender and nausea. The Cramer's V value is 0,115 (p = 0,299) and therefore we can conclude that there is no relationship between these variables.

Sense of balance

The results show that there is a weak connection between gender and balance. The Cramer's V value is 0,156 (p = 0,11) and therefore we can conclude there is weak relationship between these variables. Se figure 47.

Women have a slightly higher chance to lose balance but the difference between genders are minimally acceptable.

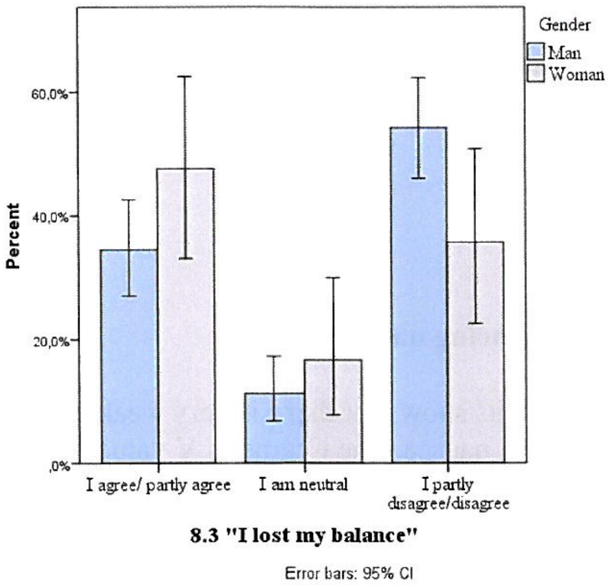

Figure 47: The connection between gender and losing balance.

Conclusion

Since the Cramer's V value is so weak on all three variables and p>0,005 we can conclude that there is no connection between gender and simulation sickness. However, women have a slightly higher chance to get simulation sickness symptoms but the difference between genders are too weak to support the hypothesis. We discard hypothesis 7.

5.4.8 Use of technology and simulation sickness

H8: "People that use technology on a regular basis get less affected by simulation sickness."

To put this hypothesis to the test the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the respondents who use technology on a regular basis, question 5. To analyze what "technology on a regular basis" means, we chose the respondents who checked 3 boxes or more. See attachment 5, section 8 for source data.

Experiencing dizziness

The results show that there is a weak connection between using technology on a regular basis and nausea. The Cramer's V value is 0,193 (p = 0,033) and therefore we can conclude that there is weak relationship between these variables. See figure 48.

The respondents who uses technology on a regular basis have a slightly higher chance to experience dizziness, but the difference between them and those who does not use it regularly is weak.

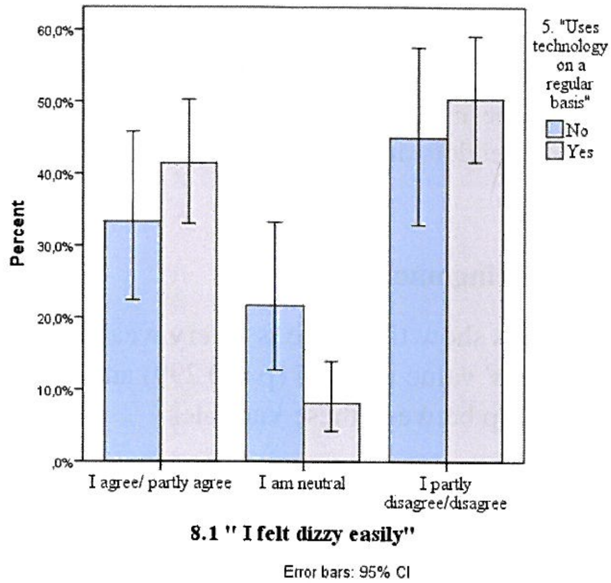

Figure 48: Connection between using technology on a regular basis and experience dizziness with Oculus Rift.

Experiencing nauseous

The results show that there is very weak connection between using technology on a regular basis and nausea. The Cramer's V value is 0,006 (p = 0,997) and therefore we can conclude that there is no relationship between these variables.

Sense of balance

The results show that there is a very weak connection between using technology on a regular basis and balance. The Cramer's V value is 0,022 (p = 0,955) and therefore we can conclude there is no relationship between these variables.

Conclusion

Since the Cramer's V value is so weak on all three variables and p>0,005 we can conclude that there is no connection between the use of technology on a regular basis and simulation sickness. The result from both sides were almost identical to each other on all the variables, so the use of technology has no effect on the user and the chance to get simulation sickness symptoms. We discard hypothesis 8.

5.4.9 IPD and simulation sickness

H9: "Users with lower or higher IPD than average have a higher chance to get simulation sickness than users with an IPD close to the average."

As mentioned in 4.3.4 IPD Measurement, we had to change our method of IPD measurement. This happened in the midst of our project after we took a closer look at the photos gathered and noticed that we could not use these to measure IPD as the respondents eyes often appeared somewhat cross-eyed. To measure and use these data would result in invalid IPD data and would cause measurement error in the thesis.
Due to this unfortunate outcome collected data from 'the ruler method' have been analyzed. See the results in figure 49 (attachment 5, section 9 for source data).

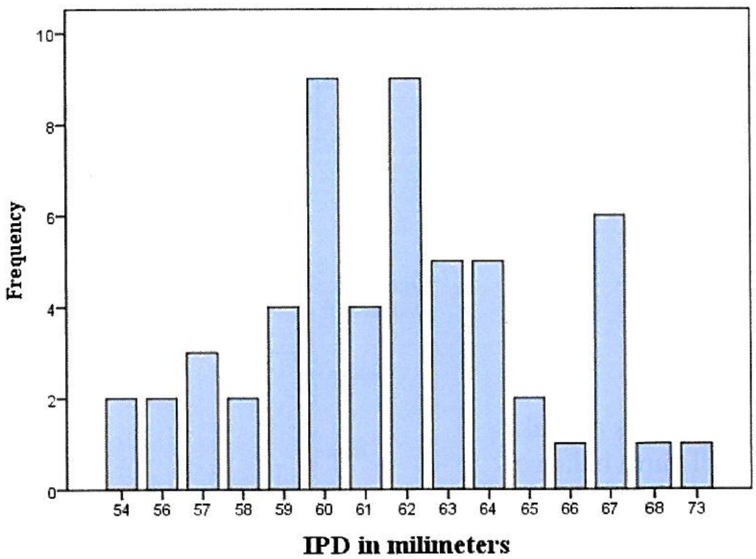

Figure 49: Respondents IPD collected by the ruler method.

Figure 49 represents the result of IPD measurement of 56 respondents, using the ruler method. We have split these results into groups; low IPD (54-62mm), close to average/average (63-65mm) and high IPD (66-73mm) for testing H9. As mentioned in 3.2.2 Interpupillary distance (IPD), the average IPD is 64mm.

To put this hypothesis to the test the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared with the IPD groups.

Experiencing dizziness

The results show that there is a moderate connection between IPD and dizziness. The Cramer's V value is 0,219 (p = 0, 27) and therefore we can conclude there is a relationship between these variables. See figure 50.

The "low IPD" and "average" groups have a higher chance to experience dizziness than the group "high IPD".

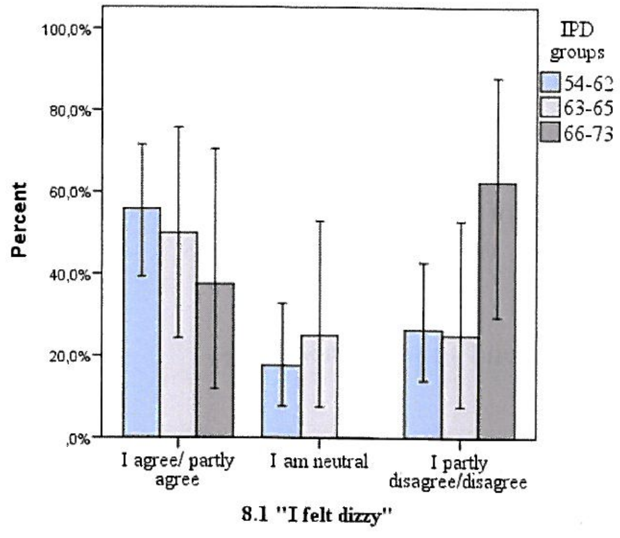

Figure 50: Connection between IPD and feeling dizzy with Oculus Rift.

Experiencing nausea

The results show that there is a moderate connection between IPD and nausea. The Cramer's V value is 0,202 (p = 0,354) and therefore we can conclude that there is a relationship between these variables. See figure 51.

Looking at the results from variables "I agree/I partly agree", the "low IPD" and "high IPD" groups have a slightly higher chance to experience nausea.

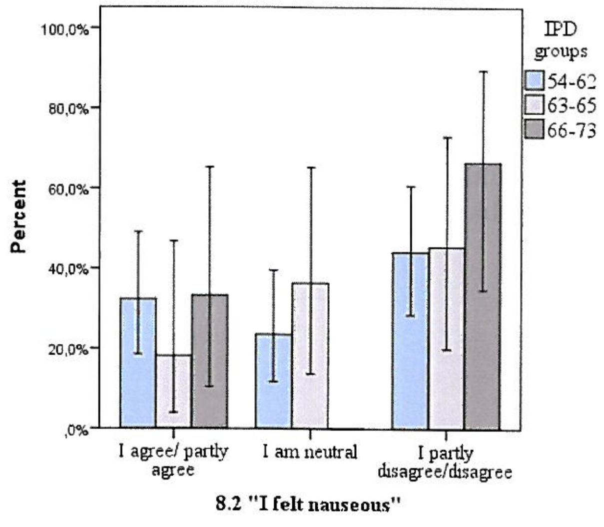

Figure 51: Connection between IPD and experiencing nausea with Oculus Rift.

Sense of balance

The results show that there is a weak connection between IPD and balance. The Cramer's V value is 0,188 (p = 0, 43) and therefore we can conclude that there is a weak relationship between these variables. See figure 52.

The "low IPD" group has a slightly higher chance to experience balance issues. The "average" and "high" groups are almost identical.

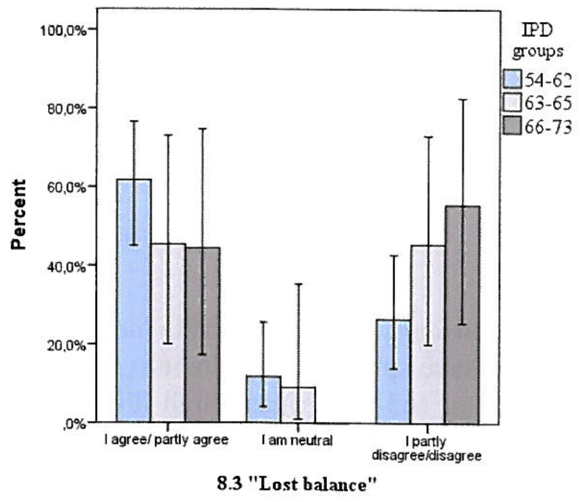

Figure 52: Connection between IPD and losing balance with Oculus Rift.

Conclusion

Since the Cramer's V value is moderate in two out of three variables and p>0,005 we can conclude that there is a relationship between IPD and simulation sickness. The group within "low IPD" have a higher chance to experience simulation sickness symptoms than the "average" group. The group within "high IPD" have a higher chance to experience nausea than "average" but less chance to experience dizziness.

Looking at the hypothesis, we can confirm that people with lower IPD than average has a higher chance to experience simulation sickness than people with an IPD close to the average.

However, even though there is a difference in the results in dizziness and sense of balance within "high IPD" and "low IPD", we can see in figure 51 that the probability of experiencing nausea are the same for both groups.

Considering these discoveries we want to keep H9 but adjust the hypothesis to *"Users with lower IPD than average have a higher chance to get simulation sickness than users with an IPD close to the average."*

5.4.10 IPD and comfortableness with Virtual Reality

H10: "Users with lower or higher IPD than average have more problems wearing the Oculus Rift than users with an IPD close to the average."

To put this hypothesis to test the results from question 11 in the questionnaire were analyzed and compared with the IPD groups (mentioned in 5.4.9). This was a multiple choice question.

11. "Did you have any problems with wearing the headset or the lenses?"												
	Yes, the lenses bothered me a bit			Yes, I was bothered because I normally wear glasses			Yes, the headset were uncomfortable			No, it was fine		
IPD	Low	Average	High	Low	Average	High	Low	Average	High	Low	Average	High
N	3	1	0	3	0	1	0	1	0	30	10	8

Figure 53: Connection between IPD and comfort using the Oculus Rift DK2 headset.

As the figure 53 shows, most of the respondents had no issues using the headset or lenses. The majority of the respondents who did experience problems/uncomfortableness lies within the group "low IPD". However, we have too little data to determine if there is any truth to the hypothesis.

5.4.11 Eyesight and simulation sickness

H11: "Eyesight has an effect on experiencing simulation sickness symptoms when using Oculus Rift."

To put this hypothesis to the test the results from question 8.1, 8.2 and 8.3 in the questionnaire were analyzed and compared them with the results from question 4.1 (eyesight). However, the results from question 4.2 were included to be able to use the collected data. This is because question 4.2 represents whether the respondents with reduced vision were wearing glasses or contact lenses at the day of testing the demo.

The respondents who answered that they were using lenses were put in the group with normal eyesight, due to the lenses ability to correct vision. Keeping them separate from the group with normal vision could lead to measurement errors in the analysis. The respondents who answered that they were wearing glasses had to take these off during the test (since glasses cannot fit under the VR goggles) and were therefore kept in their respective groups of eyesight.

We decided to focus on the respondents with normal, nearsighted and farsighted vision and have therefore excluded 12 respondents that has other diversions or misalignments. See attachment 5, section 10.

Experiencing dizziness

The results show that there is a very weak connection between eyesight and dizziness. The Cramer's V value is 0,101 ($p = 0{,}5$) and therefore we can conclude that there is no relationship between these variables.

Experiencing nausea

The results show that there is a weak connection between eyesight and nausea. The Cramer's V value is 0,154 ($p = 0{,}098$) and therefore we can conclude that there is a weak relationship between these variables.

Sense of balance

The results show that there is a very weak connection between eyesight and balance. The Cramer's V value is 0,072 ($p = 0{,}785$) and therefore we can conclude that there is no relationship between these variables.

Conclusion

Looking at the very weak and weak connections ($p > 0{,}005$) between all three variables and eyesight, we can conclude that there is no relationship between eyesight and the chance of experiencing simulation sickness symptoms. We discard hypothesis 11.

Astigmatism

When looking at eyesight as a variable, we came up with an extra question regarding astigmatism; *"How do people with astigmatism react to the experience?"*
4 respondents from the population list said they have astigmatism, and as mentioned in section 3.2.4 Depth perception, misalignments could affect 3D vision. The results from question 8.1, 8.2, 8.3, 8.6 and 8.7 from the questionnaire were analyzed to see if there were any connections.

Subject	8.1 I felt dizzy easily	8.2 I felt nauseous	8.3 I lost my balance	8.6 I got a stomach drop	8.7 I lost grip of reality
88	I agree/partly agree	I am neutral	I agree/partly agree	I am neutral	I am neutral
103	I partly disagree/disagree	I agree/ partly agree	I partly disagree/disagree	I partly disagree/disagree	I partly disagree/disagree
129	I agree/partly agree	I partly disagree/disagree	I am neutral	I partly disagree/disagree	I agree/partly agree
182	I partly disagree/disagree	(Missing data)	(Missing data)	I am neutral	I am neutral

Figure 54: Answers from the questionnaire from subject 88, 103, 129 and 182.

As seen in figure 54, the answers are varied. Considering the misalignment and the probable limitations, it is interesting to see their diverse reactions to the experience. However, due to the fact that the group is so small, we cannot further analyze these data.

5.5 Observational data

Based on the results from hypothesis 1-11 we found some variables that tells us which of the respondents who are more prone to experience simulation sickness symptoms and who are less likely to get them. The data from their observation during the test, and their answers regarding simulation sickness, were used for this analysis.

5.5.1 The target group more likely exposed to simulation sickness

After reviewing the results in our hypotheses, an assumption can be made:

Women in the age group 31-40 years old with lower IPD than average and who get sick traveling by car or bus, are more exposed to simulation sickness symptoms during the usage of Oculus Rift DK2. Subject 157 and 174 are in this target group.

Observation and results from subject 157

The respondent sits upright with hands in the lap and a big smile on her face. Looks carefully to the sides. Looks down, twitches and grabs the chair followed by laughter. She leans forward and grabs the back of the chair and seems slightly nervous.

Observation and results from subject 174

The respondent sits upright with her hands in her lap, looking straight forward during the entire demo.

Answers from questionnaire:

Subject	8.1 I felt dizzy easily	8.2 I felt nauseous	8.3 I lost my balance	8.7 I lost grip of reality
157	I partly agree	I am neutral	I partly agree	I partly agree
174	I agree	I disagree	I partly disagree	I partly agree

Figure 55: Answers from the questionnaire from subject 157 and 174.

We can conclude that subject 157 was "convinced" that what she saw was effecting her sense of reality. She lost her balance and grip of reality. She also experienced dizziness, but without nausea, we can assume she did not get simulation sick, but got dizzy because of the movement of the demo (and the combination with losing grip to reality).

Subject 174 felt dizzy and lost grip to reality, but avoided nausea and losing her balance. This could be because she was sitting calmly during the demo without looking around. The dizziness could come from the fact that the respondent had a lower IPD than what the Oculus Rift SDK settings are configured with.

Even though we discarded the hypothesis suggesting that women experience more simulation sickness, women have a slightly higher chance, but not strong enough to conclude it as a fact. See section 5.4.7. As mentioned in 5.4.6 FPS and simulation sickness, the frame rate is important to get the realistic feeling. This variable has not been a factor used in analyzing this section.

5.5.2 The target group less likely exposed to simulation sickness

Men in the age group 18-24 years old with higher IPD than average and who rarely get sick traveling by car or bus, are less likely to experience simulation sickness symptoms during the usage of Oculus Rift DK2. Subject 131, 149 and 150 are in this target group.

Observations and results from subject 131

The respondents tilts his head to the sides early in the demo. He nods forward. Has a calm pose during the test. He talks a lot in the beginning of the demo. When the demo was done, he told us that he got nauseous.

Observation and results from subject 149

The respondent informs us that he is afraid of heights. Sits calmly in the beginning, with his hands in his lap and a serious expression in his face. Looks slightly to the side; twitches, get surprised and whisper swear words. He leans backwards and starts talking louder. He uses strong verbal expressions several times including "no!" and a couple of swear words. The respondent gets restless legs and a troubled pose as he starts wobbling.

Observation and results from subject 150

Starts in a calm pose, looking straight forward. The respondent begins to laugh with a low voice. Has a calm attitude and looking forward through the whole demo. After the demo ended, he told us that he thought he moved around a lot.

Answers from questionnaire:

Subject	8.1 I felt dizzy easily	8.2 I felt nauseous	8.3 I lost my balance	8.7 I lost grip of reality
131	I agree	I partly agree	I partly agree	I am neutral
149	I partly disagree	I disagree	I disagree	I am neutral
150	I partly agree	I disagree	I agree	I agree

Figure 56: Answers from the questionnaire from subject 131, 149 and 150.

Subject 131 had a calm pose and did not show any physical signs for losing balance or dizziness, he experienced all simulation sickness symptoms. He did not feel that he lost the grip of reality but informed us after the demo that he got nauseous.

Even though subject 149 had strong physical and verbal expressions during the test, he did not agree on any of the questions regarding simulation sickness symptoms. We can assume that he had a good experience with the Oculus Rift DK2 since he did not experience any unpleasantness and the demo was realistic.

Subject 150 did not show any physical signs of balance issues or dizziness during the test, but the respondent claimed he was looking around and was swaying. In the survey he told us that he got dizzy, lost his balance and lost grip of reality. We can assume that the experience with the demo felt realistic and that the respondent did not get simulation sick because he did not get nauseous.

As the results show, there is a variation in answers and behavior between the respondents. Even though the data suggest that this target group are less likely to experience simulation sickness symptoms, it does not mean that the target group has the more realistic experience with the Oculus Rift. As mentioned in 5.4.6 FPS and simulation sickness, the frame rate is important to get the realistic feeling. This variable has not been a factor used in analyzing this section.

5.5.3 Children and the demo experience

Another group of users that is worth looking deeper into is the younger respondents. The subjects mentioned in this section are from the age group 0-12. All the respondents in this section are from SpillExpo in Lillestøm, and many of the participants had friends or family with them during the test. One of the reasons this group is interesting is because of the possibility of the Hawthorne effect, mentioned in section 4.6.

Observation and results from subject 70

Sits relaxed, looks around sometimes. The respondent's head wobbling lightly.

Observation and results from subject 71

Sits leaned forward. Looks around often. Hands in lap.

Observation and results from subject 80

The respondent talks to friends standing around him (Friends are encouraging the respondent to turn around). Seemed nervous at the beginning of the demo. The respondent use the body often to look around. Verbal expressions; "wooh!" "waah" "oh no" "the chair is tilting!". Holds on to the table.

Observation and results from subject 90

"Oh, it tickles in my tummy!" Looks backward. Uses head a lot to look around. "It's insane!" "woah!" Laughing. Grabs the chair. "What is this? waah!" Looks up, wobbling lightly. Tells friends what he sees. Grabs chair and leans back in the chair.

Observation and results from subject 97

The respondent uses his head too look around in the beginning. Uses whole body to look backwards and to the sides several times. Looks around often. Wobbling with the whole body. Often follows the movement of the demo.

Subject	8.1 I felt dizzy easily	8.2 I felt nauseous	8.3 I lost my balance	8.7 I lost grip of reality
70	I disagree	I disagree	I disagree	I disagree
71	I disagree	I disagree	I disagree	I partly agree
80	I disagree	I disagree	I disagree	I partly agree
90	I partly disagree	I disagree	I am neutral	I disagree
97	I agree	I partly agree	I disagree	I agree

Figure 57: Answers from the questionaire from subject 70, 71, 80, 90, 97.

Subject 70 did not feel any of the symptoms of simulation sickness and did not feel that he lost grip of reality. As the observation shows, the respondent was relaxed throughout the demo without any strong physical reactions.

Subject 71 was also calm but looked around more often than subject 70. He did not have any of the symptoms of simulation sickness but partly agreed on losing grip of reality.

Subject 80 talked a lot with his friends during the demo, he did not feel any symptoms of simulation sickness but partly agreed on losing grip of reality. The observation shows that he was more engaged in the experience both physically and verbally.

Subject 90 gives an indication of a stomach drop by saying "it tickles in my tummy!". He did not have any symptoms of simulation sickness but answered "I am neutral" on balance. The respondent did not lose grip of reality.

Subject 97 use the body often to look around and seems dedicated to the experience. He experienced dizziness and nausea but did not lose balance. The respondent also agreed to losing grip of reality.

We can assume that subjects 71 and 80 may have an IPD closer to the average than the other subjects in this section, because of their lack of symptoms of simulation sickness and the fact that they to some degree felt that they lost grip of reality.

Subject 70 were calm during the demo and had no symptoms of simulation sickness. As a contrast, Subject 97 felt the symptoms during the demo. A reason for this could be that the subject 97 were more physically active (looking around) than subject 70.

However, these are only an assumptions since there are no IPD data on these subjects. (See section 4.3.4)

There is a contrast in behavior during observation and the given answers for subject 90. We suspect a Hawthorne effect in motion because he had friends watching, but have no foundation to confirm this suspicion.

As mentioned in 5.4.6 FPS and simulation sickness, the frame rate is important to get the realistic feeling. This variable has not been a factor used in analyzing this section.

6 Conclusion and discussion

In this final chapter we will go through the conclusions for the project research questions. We will establish a set of guidelines for the developers, discuss what we have learned in this process and account for what could have been done differently.

6.1 Conclusion

After the research and analyzing process, we have found some answers to our research questions.

RQ1: How does different groups of users react to the usage of the Oculus Rift?

RQ2: Is there a pattern or a certain group of users that is more exposed?

RQ3: Is it possible to establish a set of guidelines for developers to ensure that the target audience won't experience severe simulation sickness symptoms during/after the experience with VR googles?

6.1.1 Looking into research question 1 and 2

The population list consists of different kinds of people; young and old, different educations, different experiences with technology, history of motion sickness etc. Looking at the results from the analysis chapter, we were not surprised to find that they react differently to the usage of the Oculus Rift.

Different groups of users reacting to the Oculus Rift

Dizziness, disorientation and symptoms of simulation sickness are some of the important answers from the respondents, but they also answered that they did not feel insecure, scared or afraid to get hurt. The majority of the respondents answered that it was a fun experience, therefore we can conclude that even though the users could experience feelings of being somewhat uncomfortable, they are generally not afraid of a virtual reality experience. See figure 27 and figure 28.

Confirming the conclusion above, the majority of the respondents who are afraid of heights had a fun experience testing the demo. See 5.1.1.

There is no connection between the groups of users with or without experience with the Oculus Rift and experiencing symptoms of simulation sickness. See figure 32. Neither is there a connection between using technology on a regular basis and symptoms of simulation sickness. See section 5.4.8.

People that are prone to get motion sickness traveling by car/bus or boat/ferry are more exposed to get symptoms of simulation sickness. See section 5.4.4 and 5.4.5.

There is no connection between gender and experiencing symptoms of simulation sickness See section 5.4.7.

The majority of the respondents answered that they believe that the sensation of moving could cause feelings of unwellness when using the Oculus Rift. See figure 31. Our results on hypothesis 6 (5.4.6) supports this assumption, as well as the fact that the brain needs at least 15 FPS to believe that what it sees is actually moving (Clarkson, 2009).

People with an IPD lower than the population average have a higher chance of experiencing dizziness than people with higher IPD. (See figure 50). People with an IPD lower or higher than average have a higher chance of feeling nauseous with the usage of Oculus Rift (See figure 51). People with an IPD close to the average felt less nauseated than the other two IPD groups, most likely because they have the correct (or close to correct) vision, matching the default settings set in the Oculus Rift SDK. This means that their eyes have the best probability of no distortion and the best perception.

Surprisingly, our results show that eyesight (normal or reduced vision) does not trigger symptoms of simulation sickness. See section 5.4.11.

Certain group of more exposed users

After looking over the results from our hypotheses, we found out that people in the age group 31-40, with a lower IPD than average and who often get sick traveling by car or bus are a target group more exposed to get symptoms of simulation sickness. See sections 5.4.2, 5.4.9 and 5.4.4.

6.1.2 Looking into research question 3

The Oculus team already have their recommendations and helpful manuals. There is no point for us to try to "reinvent the wheel" but after this project we have realized the importance of these manuals and guides. This means that it is important for both users and developers to properly read these. However, there are a few key factors we would like to emphasize.

Guidelines for developers developing a virtual reality experience

Take into consideration what kind of experience you want to create. You might not need realistic graphics if it will cause FPS drops.

Learn about timewarp and asynchronous timewarp and see if implementing these techniques can help reduce any problems regarding latency and FPS drops.

It could be an idea to remind the users to adjust the SDK settings before running the application to minimize the chances of uncomfortableness.

Give the user the option of adjusting the quality settings on the application to fit their computer hardware.

Guidelines for users of the virtual reality technology Oculus Rift DK2

Do not underestimate the adjustments for IPD to make sure the Oculus Rift is properly calibrated. This can be done with the calibrating system in Oculus Rift SDK. This also includes the 'Eye Relief' settings in the SDK and on the headset.

An optometrist can help measure the IPD if desirable.

If possible, adjust the quality settings on the application. The experience will only be as good as your computer hardware allows it to be.

6.2 Discussion

There is no doubt that for this kind of project one would need a computer with a strong graphics card. We strongly advise users and developers who want to use the Oculus Rift to not limit the computer to average graphics. We agree with the Oculus team and their recommended requirements (3.4 Oculus Rift Development Kit 2) and that a computer should be able to run steadily at minimum 55 - 60 FPS or preferably higher to make sure to keep the realistic feeling and avoid latency. See section 5.3, 5.4.6.

The respondents who tested the demo with high FPS count experienced more symptoms of simulation sickness than the group that tested with lower FPS. However this does not mean that it is a more pleasant experience with low FPS. After these findings we can assume that higher FPS gives you a more realistic feeling of the virtual reality experience.

As previously concluded, knowing the IPD either beforehand or adjusting it with the Oculus Rift SDK, is important to decrease the chances of simulation sickness.
This confirms how important it is to adjust the headset and Oculus Rift SDK settings properly, to help minimize unpleasantness while using the Oculus Rift. A few millimeters off could trigger feelings of uncomfortableness.

Looking at the observations, the Hawthorne effect has to be taken into consideration. In Kendra Cherry's article "What is the Hawthorne effect?" it is suggested that to minimize the chances of the effect one can make sure that the respondent's participation is anonymous (Cherry, undated). As both the questionnaire and the observation notes have no means of identification, we hope that we have accomplished this.

There are a lot of technical and (humanly) physical factors to consider when developing a virtual reality experience.

6.2.1 What could have been done differently?

Even though we are pleased with the outcome of the project and how we handled things, there are things that could have been done differently.

Questionnaire

A digital version of the questionnaire would have saved us the time we used preparing the collected data for the analysis tool IBM SPSS Statistics.

Observation

To make the observations of the respondents easier for us to manage we should have designed a form with measurement scales to measure the amount of body movement, head movement, speech/expressions and balance during the four minute test. This would have given us more rich data for analyzing the physical reactions.

The scene

If we had the opportunity, we would have liked to have the testing done in a closed environment to avoid the possibility of the respondent getting inattentive. This way there would be no interferences from traffic of people walking by, conference speeches or people stopping by to watch, talk or ask questions. This could also possibly decrease the chances of the Hawthorne effect because it would anonymize the respondent more.

Equipment

We were traveling to participate with the survey on different conferences, and had to rely on a laptop that was meant for video editing. In other words; to do things differently, either we would have had to do the practical part of the project on a totally different manner (not traveling and thus enabling ourselves to use a desktop computer with a high-end graphics card) or somehow get our hands on a more powerful laptop.

IPD measurement

We learned about the importance of interpupillary distance early while doing research, which means that we probably should have booked the meeting with optometrist Richard Nilsen at Synsam Steinkjer Synssenter at an earlier stage.

If we had known about the "ruler method" before starting the project (or the possibility to rent a specially designed "binocular device" for measuring IPD) we would probably have a complete set of IPD data for the entire population list.

FPS measurement

The use of "high" and "very low" quality settings on the demo to test FPS changes was a mid-project idea which should probably have been set as a goal from the start of the project. The findings we got from comparing the two groups were interesting but if we had the time, we would have added an additional group using the "normal" quality settings to have third set of variables for the analysis.

6.2.2 End note

We have not made any changes to the project that would alter the end result and conclusions in any way. All changes have been made to improve how we could see differences and properly test our research questions.
The changes we have done, like the IPD measurement method and demo settings regarding FPS, have not changed the collected data, but have improved it and made it more reliable.

The alternations mentioned that we didn't have the opportunity to do, would have given us another layer of rich data and "upgraded" the level of results. This could have been done if we had more time with the project.

Lastly, the technology of virtual reality is still under the scope and developers and engineers are working on it every day worldwide. This means that there are still so much to account for on a deeper level; positional timewarp, orientational timewarp, eye vergence/focus, eye tracking, computer hardware etc. Considering these possible influences, it will be very interesting to follow the development of this technology in the future.

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Attachments

Attachment 1: E-mail from Oliver Kreylos

Attachment 2: E-mail from Sebastian Kuhlen

Attachment 3: Questionnaire

Attachment 4: Measurement of association

Attachment 5: Source data.

Attachment 1

Oliver Kreylos <okreylos@ucdavis.edu>
sø 25.01.2015 02:31
Innboks

On 01/23/2015 06:39 AM, Lisa Jørgensen wrote:
> We are currently writing the theory part, and have done research about
> motion and simulation sickness, basics of the eye functions and are now
> focusing on importance of IPD and calibration (and will also write also
> FOV, FPS and resolution).
> I found your blog and your youtube video very helpful and hope to use
> them as part of my references.
>
> However, I was hoping you could have a look at the screenshot (from my
> word file) and tell me if I have understood your video correctly.

Hi Lisa,

yes, you got it.

Explaining calibration and perception with the lenses in place unnecessarily complicates things, I think. I would do the explanation of IPD and eye relief without the lenses until the idea really sinks in, and then mention afterwards that things are more complex in reality because there have to be lenses between the screens and eyes, but that the same principles apply.

Make sure to explain precisely why the lenses are there, because I've noted that many people, even those who have thought about it, don't understand. I think it's useful to spend one or two diagrams on that. The first part is that the lenses optically project the screens out to infinity (or 1.3m for the Rift DK2), so that the viewer can actually focus on them. Many people can't get over the fact that the Rift's lenses are only a few centimeters in front of the viewer's eyes, and get hung up on how that must be very uncomfortable.

The second lens effect is a magnification of the screen, so that the actual field of view is somewhat larger than the FOV without lenses, but that effect is smaller than many people assume. The DK2's (theoretical) FOV without lenses is around 75 degrees, and with lenses around 100 degrees.

Don't worry about the follow-up video. It's about another approximation of IPD that gets around the problem that IPD changes in response to vergence (the eyes rotating inwards). A person's measured IPD is "infinity IPD," when the eyes are parallel to look at an infinitely-far away object. Near-IPD is a couple of millimeters less, but since the Rift doesn't have eye tracking, it can't adjust for it. Setting the eye position to the center of the eyeball instead the pupil is an approach that distributes projection artifacts more evenly over a larger vergence range. But it's a "hack," and I wouldn't put too much emphasis on it.

Hope this helps,

Oliver

Email: kreylos@cs.ucdavis.edu
WWW: http://idav.ucdavis.edu/~okreylos/ResDev
Blog: http://doc-ok.org

Attachment 2

Sebastian Kuhlen <mail@skuhlen.de>
ma 04.05.2015 20:08
Innboks
Til:
Lisa Jørgensen;
Kopi:
Stine Hansen Bendiksen;
Hi Lisa and Stine,

it's great to hear that you could use my demo for this. It's been a while since I last worked on Atlantis, although there are still a few things I wanted to add. I hope to get back to this some time...

So, to answer your question, I use the max fov. By this I mean, that I do not set the FOV manually, but request the Oculus SDK (the demo is still using version 0.4.3, if I am not mistaken) to create a projection matrix that gives the maximum possible FOV. I am not sure if this is the answer you are looking for, but unless a developer wants to gain a little perfomance boost by intentionally reducing the FOV, it should mostly be the same for all demos and change with different user settings (eye relief, IPD etc.)... The difference between MaxEyeFov and DefaultEyeFov should not be big either for most users and the only reason I am using MaxEyeFov is to circumvent a rare bug, when the user calibration is broken and totally off. After all the "correct" FOV is determined by where the eyes are in relation to the optics and the screen - and if the user did the calibration correctly, the SDK knows best about this.

A note regarding the way you measure the FPS:
I use my own implementation of asynchronous timewarp in the demo. I am not sure if there is an official implementation for this by now, but a quick search did not come up with any... The idea is, that the rendering is split into two independent threads. The main thread renders the scene as fast as possible to off-screen memory. The second thread sits and waits for v-sync, doing nothing until the very last moment before the next refresh is shown on the VR screen. It then picks the latest rendering from the main thread, applies timewarp and presents it to the user.
The idea is, that even if the framerate drops below 75fps, you get a timewarped image on every single frame. If necessary you get the same rendering twice, but individually corrected for your head rotation. Conventional timewarp is only applied once per rendered frame, so head rotations tend to stutter more when the framrate drops. Using asynchronous timewarp, in theory, the framerate may drop down a lot (50fps or lower) before the turning of your head feels weird. Unfortunately, in my tests it introduced some different micro stuttering, which I could never fix. So, on weak machines my demo might work surprisingly well, but on fast machines, on which you did not expect any stuttering at all, this micro stuttering remained somewhat apparent.

The point is, that the FPS you recorded may not be the rate at which the scene is rendered but the rate at which the scene is presented to the user, which should be solid 75fps. If you want to be sure, you can run the game using the custom settings or edit one of the other graphic presets. In /resources/config/ you will find cfg-files corresponding to the presets and you can edit them using any text editor (except for the windows editor, which might have trouble with linux style line breaks). If you set LogLevel to 3 for the setting you use, the FPS measured by the game will be written to the file atlantis.log - This is the rate at which the scene is actually rendered.

I am not sure whether FPS is relevant to your thesis, but in this regard my demo is probably a rather unique one...

Well, I think this is enough text for one mail :) Sorry, if some of the information is too simplified or too complicated - I am not familiar with your course of studies and how technical it is. BTW, can you tell me the subject of your thesis? Will it be published somewhere?

If you have any more questions or need some other details, please let me know.

Greetings and good luck with your thesis,
Sebastian

Attachment 2

Attachment 3

Subject:

OCULUS RIFT EXPERIENCE SURVEY

The data in this survey will be used as research material in a bachelor assignment.

PHOTOSENSITIVITY/MOTION SICKNESS/SEIZURES

THE HEADSET PRODUCES AN IMMERSIVE VIDEO EXPERIENCE, WHICH CAN HAVE ADVERSE EFFECTS ON THE USER, INCLUDING SIMULATION SICKNESS, PERCEPTUAL AFTER EFFECTS, DISORIENTATION, DECREASED POSTURAL STABILITY, AND EYE STRAIN. SOME INDIVIDUALS MAY ALSO EXPERIENCE SEVERE DIZZINESS, EPILEPTIC SEIZURES, OR BLACKOUTS WHEN EXPOSED TO CERTAIN FLASHING LIGHTS OR PATTERNS LIKE THOSE PRODUCED BY THE HEADSET.
Participants use the VR goggles at their own risk after reading this warning.

1. Gender:

O Man　O Woman　O Other

---

2. Age:

O 0-12　O 13-17　O 18-24
O 25-30　O 31-40　O 41-50
O 51-60　O 61-70　O 70 +

---

3. Highest education:

O Primary School *(Up to 15 years old)*　O Secondary School *(16 -19 years old)*
O College *(BA degree)*　O University *(MA degree)*

4.1 Eye sight:

O Normal
O Nearsighted
O Farsighted
O Other

- If other, please explain:

4.2 Do you use glasses or lenses now?

O Glasses

O Lenses

4.3 If you use lenses or glasses, Please state the strength you need per eye:

Right eye: ……………………..　Left eye: ……………………

Subject:

5. Which of the listed technologies do you use on a regularly basis? *Check any that apply:*

☐ Smartphone

☐ Tablet

☐ PC/Mac

☐ Virtual Reality headset

☐ Video Game Console *(Xbox ,PlayStation 3 / 4 etc.)*

☐ Handheld video game device *(DS, PS Vita etc.)*

6. Have you tried Oculus Rift before? Check any that apply:

☐ Yes (the Oculus) ☐ Other Virtual Reality headset

☐ No ☐ I don't remember

- If other headset than the Oculus Rift, which one?

....

7. The next statements regards travel/motion/simulation sickness.
Please mark your answer with an "X":

		Always	Sometimes	Neutral	Rarely	Never	I don't know
7.1	I often feel nauseous/sick when I travel by car or bus.						
7.2	I often feel nauseous/sick when I travel by train.						
7.3	I often feel nauseous/sick when I travel by airplane.						
7.4	I often feel nauseous/sick when I travel by boat/ferry.						
7.5	When I play video games I get motion sick very easy						
7.6	I am afraid of heights						
7.7	I enjoy rollercoasters/ other stomach dropping attractions						

Subject:

AFTER the experience

8. Please mark your answer with an "X":

		I agree	I partly Agree	I am Neutral	I partly disagree	I disagree	I don't know
8.1	I felt dizzy easily.						
8.2	I felt nauseous.						
8.3	I lost my balance						
8.4	I felt disoriented						
8.5	I got an adrenaline rush						
8.6	I got a stomach drop *(rollercoaster feeling)*						
8.7	I lost grip of reality						
8.8	I felt scared						
8.9	I felt insecure						
8.10	I felt that I lost control						
8.11	I was afraid that I would hurt myself						

9. Please mark your answer with an "X":

		I agree	I partly Agree	I am Neutral	I partly disagree	I disagree	I don't know
9.1	It was a fun experience						
9.2	I felt excited						
9.3	I felt surprised						
9.4	I felt bored						
9.5	I felt emotionally moved						
9.6	I would want to try Oculus Rift again						
9.7	I would like to try other Virtual Reality headsets						
9.8	The picture quality was satisfying						
9.9	The colors did not bother me						

Subject:

9.10	The lighting did not bother me						

10. If you felt sick or nauseous, what did you do to stop it?

- ☐ I did not feel sick
- ☐ I tried to focus ahead of me
- ☐ I tried to orientate to the surroundings
- ☐ I took the headset off
- ☐ Nothing
- ☐ Other

- If other, please explain:

....

11. Did you have any problems with wearing the headset or the lenses? *Check any that apply:*

- ☐ Yes, the lenses bothered me a bit
- ☐ Yes, I was bothered because I normally wear glasses
- ☐ Yes, the headset was uncomfortable
- ☐ No, it was fine

12. What do you think can cause feelings of unwellness/nausea with the use of Oculus Rift?

- ☐ High-Contract Colors / Color experience
- ☐ Lighting
- ☐ Quick movement for the eye
- ☐ Sensation of moving
- ☐ Other (please specify below):

....

....

....

13. (Voluntary): Comments on the experience:

Measures of Association:Nominal data--Phi and Cramer's V

- ***Measures of Association*** calculate the strength, and for ordinal variables the direction, of the relationship between two variables.
    - **PHI**: Used to measure the strength of the association between two variables, each of which has only two categories. (It applies to *2 X 2 nominal* tables only).
    - **CRAMER'S V**: Used to measure the strength of the association between one nominal variable with either another nominal variable, or with an ordinal variable. Both of the variables can have more than 2 categories. (It applies to either *nominal X nominal* crosstabs, or *ordinal X nominal* crosstabs, with no restriction on the number of categories.)
- ***Interpreting the value of the Level of Association:***

LEVEL OF ASSOCIATION	Verbal Description	COMMENTS
0.00	No Relationship	Knowing the independent variable does not help in predicting the dependent variable.
.00 to .15	Very Weak	Not generally acceptable
.15 to .20	Weak	Minimally acceptable
.20 to .25	Moderate	Acceptable
.25 to .30	Moderately Strong	Desirable
.30 to .35	Strong	Very Desirable
.35 to .40	Very Strong	Extremely Desirable
.40 to .50	Worrisomely Strong	Either an extremely good relationship or the two variables are measuring the same concept
.50 to .99	Redundant	The two variables are probably measuring the same concept.
1.00	Perfect Relationship.	If we the know the independent variable, we can perfectly predict the dependent variable.

1: *(5.1.1 Other findings in the collected data of the population)*

1.1: Figure 25, Age → Sight

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Sight * Age	180	96,3%	7	3,7%	187	100,0%

Sight * Age Crosstabulation

			Age						Total
			0-17	18-24	25-30	31-40	41-50	51+	
Sight	Normal	Count	28	31	14	9	5	4	91
		% within Sight	30,8%	34,1%	15,4%	9,9%	5,5%	4,4%	100,0%
	Nearsighted	Count	3	16	16	14	9	2	60
		% within Sight	5,0%	26,7%	26,7%	23,3%	15,0%	3,3%	100,0%
	Farsighted	Count	2	3	5	4	7	5	26
		% within Sight	7,7%	11,5%	19,2%	15,4%	26,9%	19,2%	100,0%
	Nearsighted and farsighted	Count	0	1	0	0	0	2	3
		% within Sight	0,0%	33,3%	0,0%	0,0%	0,0%	66,7%	100,0%
Total		Count	33	51	35	27	21	13	180
		% within Sight	18,3%	28,3%	19,4%	15,0%	11,7%	7,2%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,569	,000
	Cramer's V	,329	,000
N of Valid Cases		180	

1.2: Figure 26, Afraid of heights → Enjoys rollercoasters

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
afraid of heights * enjoy rollercoaster	177	94,7%	10	5,3%	187	100,0%

afraid of heights * enjoy rollercoaster Crosstabulation

			enjoy rollercoaster			Total
			Always/sometimes	Neutral	Rarely/never	
afraid of heights	Always/sometimes	Count	40	10	23	73
		% within afraid of heights	54,8%	13,7%	31,5%	100,0%
	Neutral	Count	20	2	0	22
		% within afraid of heights	90,9%	9,1%	0,0%	100,0%
	Rarely/never	Count	65	7	10	82
		% within afraid of heights	79,3%	8,5%	12,2%	100,0%
Total		Count	125	19	33	177
		% within afraid of heights	70,6%	10,7%	18,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,320	,001
	Cramer's V	,227	,001
N of Valid Cases		177	

1.3: Afraid of heights and enjoy rollercoasters → felt a stomach drop

felt a stomachdrop

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I agree/ partly agree	16	40,0	41,0	41,0
	I am neutral	9	22,5	23,1	64,1
	I partly disagree/disagree	14	35,0	35,9	100,0
	Total	39	97,5	100,0	
Missing	System	1	2,5		
Total		40	100,0		

1.4: Afraid of heights and enjoy rollercoasters → fun experience

It was a fun experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I agree/ partly agree	36	90,0	92,3	92,3
	I am neutral	2	5,0	5,1	97,4
	I partly disagree/disagree	1	2,5	2,6	100,0
	Total	39	97,5	100,0	
Missing	System	1	2,5		
Total		40	100,0		

2: *(5.4.2 Different age groups and simulation sickness)*

2.1: Figure 35, Age → Dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age * felt dizzy	183	97,9%	4	2,1%	187	100,0%

Age * felt dizzy Crosstabulation

			felt dizzy			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
Age	0-24	Count	23	14	49	86
		% within Age	26,7%	16,3%	57,0%	100,0%
	25-30	Count	16	5	13	34
		% within Age	47,1%	14,7%	38,2%	100,0%
	31-40	Count	16	0	10	26
		% within Age	61,5%	0,0%	38,5%	100,0%
	41-50	Count	9	2	11	22
		% within Age	40,9%	9,1%	50,0%	100,0%
	51+	Count	7	2	6	15
		% within Age	46,7%	13,3%	40,0%	100,0%
Total		Count	71	23	89	183
		% within Age	38,8%	12,6%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,285	,062
	Cramer's V	,202	,062
N of Valid Cases		183	

2.2: Age → Nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age * I felt nauseous	184	98,4%	3	1,6%	187	100,0%

Age * I felt nauseous Crosstabulation

			I felt nauseous			
			I afree/ partly agree	I am neutral	I partly disagree/disagree	Total
Age	0-24	Count	17	9	59	85
		% within Age	20,0%	10,6%	69,4%	100,0%
	25-30	Count	6	6	22	34
		% within Age	17,6%	17,6%	64,7%	100,0%
	31-40	Count	10	3	14	27
		% within Age	37,0%	11,1%	51,9%	100,0%
	41-50	Count	5	3	14	22
		% within Age	22,7%	13,6%	63,6%	100,0%
	51+	Count	5	1	10	16
		% within Age	31,2%	6,2%	62,5%	100,0%
Total		Count	43	22	119	184
		% within Age	23,4%	12,0%	64,7%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,181	,644
	Cramer's V	,128	,644
N of Valid Cases		184	

2.3: Age → Sense of balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age * Lost balance	184	98,4%	3	1,6%	187	100,0%

Age * Lost balance Crosstabulation

			Lost balance			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
Age	0-24	Count	27	14	44	85
		% within Age	31,8%	16,5%	51,8%	100,0%
	25-30	Count	17	4	13	34
		% within Age	50,0%	11,8%	38,2%	100,0%
	31-40	Count	11	2	14	27
		% within Age	40,7%	7,4%	51,9%	100,0%
	41-50	Count	7	2	13	22
		% within Age	31,8%	9,1%	59,1%	100,0%
	51+	Count	7	1	8	16
		% within Age	43,8%	6,2%	50,0%	100,0%
Total		Count	69	23	92	184
		% within Age	37,5%	12,5%	50,0%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,185	,611
	Cramer's V	,131	,611
N of Valid Cases		184	

3: *(4.4.3 Age group 0-24 and losing grip of reality)*

3.1: Figure 36, Age → Losing grip of reality

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Age * Lost grip of reality	182	97,3%	5	2,7%	187	100,0%

Age * Lost grip of reality Crosstabulation

			Lost grip of reality			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
Age	0-24	Count	27	13	43	83
		% within Age	32,5%	15,7%	51,8%	100,0%
	25-30	Count	8	6	20	34
		% within Age	23,5%	17,6%	58,8%	100,0%
	31-40	Count	13	2	12	27
		% within Age	48,1%	7,4%	44,4%	100,0%
	41-50	Count	4	4	14	22
		% within Age	18,2%	18,2%	63,6%	100,0%
	51+	Count	3	3	10	16
		% within Age	18,8%	18,8%	62,5%	100,0%
Total		Count	55	28	99	182
		% within Age	30,2%	15,4%	54,4%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,210	,434
	Cramer's V	,148	,434
N of Valid Cases		182	

4: *(5.4.4 Motion sickness by car/bus and simulation sickness)*

4.1: Figure 37, Sick by car or bus → Dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by car or bus * felt dizzy	181	96,8%	6	3,2%	187	100,0%

sick by car or bus * felt dizzy Crosstabulation

			felt dizzy			
			I afree/ partly agree	I am neutral	I partly disagree/disagree	Total
sick by car or bus	Always/sometimes	Count	24	7	11	42
		% within sick by car or bus	57,1%	16,7%	26,2%	100,0%
	Neutral	Count	4	0	3	7
		% within sick by car or bus	57,1%	0,0%	42,9%	100,0%
	Rarely/never	Count	42	16	74	132
		% within sick by car or bus	31,8%	12,1%	56,1%	100,0%
Total		Count	70	23	88	181
		% within sick by car or bus	38,7%	12,7%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,271	,010
	Cramer's V	,191	,010
N of Valid Cases		181	

4.2: Figure 38, Sick by car or bus → Nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by car or bus * I felt nauseous	182	97,3%	5	2,7%	187	100,0%

sick by car or bus * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
sick by car or bus	Always/sometimes	Count	15	10	17	42
		% within sick by car or bus	35,7%	23,8%	40,5%	100,0%
	Neutral	Count	3	1	3	7
		% within sick by car or bus	42,9%	14,3%	42,9%	100,0%
	Rarely/never	Count	24	11	98	133
		% within sick by car or bus	18,0%	8,3%	73,7%	100,0%
Total		Count	42	22	118	182
		% within sick by car or bus	23,1%	12,1%	64,8%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,314	,001
	Cramer's V	,222	,001
N of Valid Cases		182	

4.3: Sick by car or bus → Sense of balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by car or bus * Lost balance	182	97,3%	5	2,7%	187	100,0%

sick by car or bus * Lost balance Crosstabulation

			Lost balance			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
sick by car or bus	Always/sometimes	Count	20	8	14	42
		% within sick by car or bus	47,6%	19,0%	33,3%	100,0%
	Neutral	Count	2	1	4	7
		% within sick by car or bus	28,6%	14,3%	57,1%	100,0%
	Rarely/never	Count	47	13	73	133
		% within sick by car or bus	35,3%	9,8%	54,9%	100,0%
Total		Count	69	22	91	182
		% within sick by car or bus	37,9%	12,1%	50,0%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,193	,148
	Cramer's V	,136	,148
N of Valid Cases		182	

5: *(5.4.5 Motion sickness by boat/ferry and simulation sickness)*

5.1: Figure 39, Sick by boat or ferry → dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by boat or ferry * felt dizzy	179	95,7%	8	4,3%	187	100,0%

sick by boat or ferry * felt dizzy Crosstabulation

			felt dizzy			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
sick by boat or ferry	Always/sometimes	Count	22	2	17	41
		% within sick by boat or ferry	53,7%	4,9%	41,5%	100,0%
	Neutral	Count	8	3	0	11
		% within sick by boat or ferry	72,7%	27,3%	0,0%	100,0%
	Rarely/never	Count	39	18	70	127
		% within sick by boat or ferry	30,7%	14,2%	55,1%	100,0%
Total		Count	69	23	87	179
		% within sick by boat or ferry	38,5%	12,8%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,323	,001
	Cramer's V	,228	,001
N of Valid Cases		179	

5.2: Figure 40, Sick by boat or ferry → nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by boat or ferry * I felt nauseous	180	96,3%	7	3,7%	187	100,0%

sick by boat or ferry * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
sick by boat or ferry	Always/sometimes	Count	17	6	18	41
		% within sick by boat or ferry	41,5%	14,6%	43,9%	100,0%
	Neutral	Count	4	5	2	11
		% within sick by boat or ferry	36,4%	45,5%	18,2%	100,0%
	Rarely/never	Count	21	11	96	128
		% within sick by boat or ferry	16,4%	8,6%	75,0%	100,0%
Total		Count	42	22	116	180
		% within sick by boat or ferry	23,3%	12,2%	64,4%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,403	,000
	Cramer's V	,285	,000
N of Valid Cases		180	

5.3 Sick by boat or ferry → Sense of balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sick by boat or ferry * Lost balance	180	96,3%	7	3,7%	187	100,0%

sick by boat or ferry * Lost balance Crosstabulation

			Lost balance			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
sick by boat or ferry	Always/sometimes	Count	20	5	16	41
		% within sick by boat or ferry	48,8%	12,2%	39,0%	100,0%
	Neutral	Count	4	1	6	11
		% within sick by boat or ferry	36,4%	9,1%	54,5%	100,0%
	Rarely/never	Count	45	16	67	128
		% within sick by boat or ferry	35,2%	12,5%	52,3%	100,0%
Total		Count	69	22	89	180
		% within sick by boat or ferry	38,3%	12,2%	49,4%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,124	,594
	Cramer's V	,088	,594
N of Valid Cases		180	

6: *(5.4.6 FPS and simulation sickness)*

6.1 Figure 41, FPS → Dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * felt dizzy	183	97,9%	4	2,1%	187	100,0%

High or low fps * felt dizzy Crosstabulation

			felt dizzy			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
High or low fps	Low FPS	Count	42	14	72	128
		% within High or low fps	32,8%	10,9%	56,2%	100,0%
	High FPS	Count	29	9	17	55
		% within High or low fps	52,7%	16,4%	30,9%	100,0%
Total		Count	71	23	89	183
		% within High or low fps	38,8%	12,6%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,233	,007
	Cramer's V	,233	,007
N of Valid Cases		183	

6.2 Figure 42, FPS → nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * I felt nauseous	184	98,4%	3	1,6%	187	100,0%

High or low fps * I felt nauseous Crosstabulation

			I felt nauseous			
			I afree/ partly agree	I am neutral	I partly disagree/disagree	Total
High or low fps	Low FPS	Count	27	10	92	129
		% within High or low fps	20,9%	7,8%	71,3%	100,0%
	High FPS	Count	16	12	27	55
		% within High or low fps	29,1%	21,8%	49,1%	100,0%
Total		Count	43	22	119	184
		% within High or low fps	23,4%	12,0%	64,7%	100,0%

Symmetric Measures

		Value	Approx. Sig
Nominal by Nominal	Phi	,238	,005
	Cramer's V	,238	,005
N of Valid Cases		184	

6.3: Figure 43, FPS → lost balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * Lost balance	184	98,4%	3	1,6%	187	100,0%

High or low fps * Lost balance Crosstabulation

			Lost balance			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
High or low fps	Low FPS	Count	39	18	72	129
		% within High or low fps	30,2%	14,0%	55,8%	100,0%
	High FPS	Count	30	5	20	55
		% within High or low fps	54,5%	9,1%	36,4%	100,0%
Total		Count	69	23	92	184
		% within High or low fps	37,5%	12,5%	50,0%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,230	,008
	Cramer's V	,230	,008
N of Valid Cases		184	

6.4: FPS → Picture quality good

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * Picture quality good	185	98,9%	2	1,1%	187	100,0%

High or low fps * Picture quality good Crosstabulation

			Picture quality good			Total
			Agree/partly agree	Neutral	Partly disagree/disagree	
High or low fps	Low FPS	Count	39	22	68	129
		% within High or low fps	30,2%	17,1%	52,7%	100,0%
	High FPS	Count	13	12	31	56
		% within High or low fps	23,2%	21,4%	55,4%	100,0%
Total		Count	52	34	99	185
		% within High or low fps	28,1%	18,4%	53,5%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,079	,565
	Cramer's V	,079	,565
N of Valid Cases		185	

6.5: Figure 44, FPS → Stomach drop

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * felt a stomachdrop	185	98,9%	2	1,1%	187	100,0%

High or low fps * felt a stomachdrop Crosstabulation

			felt a stomachdrop			
			I afree/ partly agree	I am neutral	I partly disagree/disagree	Total
High or low fps	Low FPS	Count	46	20	63	129
		% within High or low fps	35,7%	15,5%	48,8%	100,0%
	High FPS	Count	34	7	15	56
		% within High or low fps	60,7%	12,5%	26,8%	100,0%
Total		Count	80	27	78	185
		% within High or low fps	43,2%	14,6%	42,2%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,237	,005
	Cramer's V	,237	,005
N of Valid Cases		185	

6.6: Figure 45, FPS → Lose grip of reality

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * Lost grip of reality	182	97,3%	5	2,7%	187	100,0%

High or low fps * Lost grip of reality Crosstabulation

			Lost grip of reality			Total
			I afree/ partly agree	I am neutral	I partly disagree/disagree	
High or low fps	Low FPS	Count	33	17	76	126
		% within High or low fps	26,2%	13,5%	60,3%	100,0%
	High FPS	Count	22	11	23	56
		% within High or low fps	39,3%	19,6%	41,1%	100,0%
Total		Count	55	28	99	182
		% within High or low fps	30,2%	15,4%	54,4%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,178	,055
	Cramer's V	,178	,055
N of Valid Cases		182	

6.7: Figure 46, FPS → fun experience

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
High or low fps * It was a fun experience	186	99,5%	1	0,5%	187	100,0%

High or low fps * It was a fun experience Crosstabulation

			It was a fun experience			
			I afree/ partly agree	I am neutral	I partly disagree/disagree	Total
High or low fps	Low FPS	Count	116	10	4	130
		% within High or low fps	89,2%	7,7%	3,1%	100,0%
	High FPS	Count	51	4	1	56
		% within High or low fps	91,1%	7,1%	1,8%	100,0%
Total		Count	167	14	5	186
		% within High or low fps	89,8%	7,5%	2,7%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,038	,872
	Cramer's V	,038	,872
N of Valid Cases		186	

7: *(5.4.7 Gender and simulation sickness)*

7.1: Gender → Dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * felt dizzy	183	97,9%	4	2,1%	187	100,0%

Gender * felt dizzy Crosstabulation

			felt dizzy			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Gender	Man	Count	50	17	74	141
		% within Gender	35,5%	12,1%	52,5%	100,0%
	Woman	Count	21	6	15	42
		% within Gender	50,0%	14,3%	35,7%	100,0%
Total		Count	71	23	89	183
		% within Gender	38,8%	12,6%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,143	,152
	Cramer's V	,143	,152
N of Valid Cases		183	

7.2: Gender → Nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * I felt nauseous	184	98,4%	3	1,6%	187	100,0%

Gender * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Gender	Man	Count	30	16	96	142
		% within Gender	21,1%	11,3%	67,6%	100,0%
	Woman	Count	13	6	23	42
		% within Gender	31,0%	14,3%	54,8%	100,0%
Total		Count	43	22	119	184
		% within Gender	23,4%	12,0%	64,7%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,115	,299
	Cramer's V	,115	,299
N of Valid Cases		184	

7.3: Figure 47, Gender → Balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * Lost balance	184	98,4%	3	1,6%	187	100,0%

Gender * Lost balance Crosstabulation

			Lost balance			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Gender	Man	Count	49	16	77	142
		% within Gender	34,5%	11,3%	54,2%	100,0%
	Woman	Count	20	7	15	42
		% within Gender	47,6%	16,7%	35,7%	100,0%
Total		Count	69	23	92	184
		% within Gender	37,5%	12,5%	50,0%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,156	,107
	Cramer's V	,156	,107
N of Valid Cases		184	

8: (*5.4.8 Use of technology and simulation sickness)*

8.1: Figure 48, Technology → dizziness

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Uses technology on a regular basis. * felt dizzy	183	97,9%	4	2,1%	187	100,0%

Uses technology on a regular basis. * felt dizzy Crosstabulation

			felt dizzy			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Uses technology on a regular basis.	No	Count	20	13	27	60
		% within Uses technology on a regular basis.	33,3%	21,7%	45,0%	100,0%
	Yes	Count	51	10	62	123
		% within Uses technology on a regular basis.	41,5%	8,1%	50,4%	100,0%
Total		Count	71	23	89	183
		% within Uses technology on a regular basis.	38,8%	12,6%	48,6%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,193	,033
	Cramer's V	,193	,033
N of Valid Cases		183	

8.2: Technology → Nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Uses technology on a regular basis. * I felt nauseous	184	98,4%	3	1,6%	187	100,0%

Uses technology on a regular basis. * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Uses technology on a regular basis.	No	Count	14	7	38	59
		% within Uses technology on a regular basis.	23,7%	11,9%	64,4%	100,0%
	Yes	Count	29	15	81	125
		% within Uses technology on a regular basis.	23,2%	12,0%	64,8%	100,0%
Total		Count	43	22	119	184
		% within Uses technology on a regular basis.	23,4%	12,0%	64,7%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,006	,997
	Cramer's V	,006	,997
N of Valid Cases		184	

8.3 Technology → Balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Uses technology on a regular basis. * Lost balance	184	98,4%	3	1,6%	187	100,0%

Uses technology on a regular basis. * Lost balance Crosstabulation

			Lost balance			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Uses technology on a regular basis.	No	Count	22	8	29	59
		% within Uses technology on a regular basis.	37,3%	13,6%	49,2%	100,0%
	Yes	Count	47	15	63	125
		% within Uses technology on a regular basis.	37,6%	12,0%	50,4%	100,0%
Total		Count	69	23	92	184
		% within Uses technology on a regular basis.	37,5%	12,5%	50,0%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,022	,955
	Cramer's V	,022	,955
N of Valid Cases		184	

9: *(5.4.9 IPD and simulation sickness)*

9.1: Figure 50, IPD→Dizzy

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
IPD groups * felt dizzy	54	28,9%	133	71,1%	187	100,0%

IPD groups * felt dizzy Crosstabulation

			felt dizzy			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
IPD groups	54-62	Count	19	6	9	34
		% within IPD groups	55,9%	17,6%	26,5%	100,0%
	63-65	Count	6	3	3	12
		% within IPD groups	50,0%	25,0%	25,0%	100,0%
	66-73	Count	3	0	5	8
		% within IPD groups	37,5%	0,0%	62,5%	100,0%
Total		Count	28	9	17	54
		% within IPD groups	51,9%	16,7%	31,5%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,309	,271
	Cramer's V	,219	,271
N of Valid Cases		54	

9.2: Figure 51, IPD → Nausea

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,309	,271
	Cramer's V	,219	,271
N of Valid Cases		54	

IPD groups * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
IPD groups	54-62	Count	11	8	15	34
		% within IPD groups	32,4%	23,5%	44,1%	100,0%
	63-65	Count	2	4	5	11
		% within IPD groups	18,2%	36,4%	45,5%	100,0%
	66-73	Count	3	0	6	9
		% within IPD groups	33,3%	0,0%	66,7%	100,0%
Total		Count	16	12	26	54
		% within IPD groups	29,6%	22,2%	48,1%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,286	,354
	Cramer's V	,202	,354
N of Valid Cases		54	

9.3: Figure 52, IPD → balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
IPD groups * Lost balance	54	28,9%	133	71,1%	187	100,0%

IPD groups * Lost balance Crosstabulation

			Lost balance			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
IPD groups	54-62	Count	21	4	9	34
		% within IPD groups	61,8%	11,8%	26,5%	100,0%
	63-65	Count	5	1	5	11
		% within IPD groups	45,5%	9,1%	45,5%	100,0%
	66-73	Count	4	0	5	9
		% within IPD groups	44,4%	0,0%	55,6%	100,0%
Total		Count	30	5	19	54
		% within IPD groups	55,6%	9,3%	35,2%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,266	,430
	Cramer's V	,188	,430
N of Valid Cases		54	

10: *(5.4.11 Eyesight and simulation sickness)*

10.1 Eyesight → dizzy

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Eye sight groups * felt dizzy	164	87,7%	23	12,3%	187	100,0%

Eye sight groups * felt dizzy Crosstabulation

			felt dizzy			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Eye sight groups	Normal	Count	37	18	57	112
		% within Eye sight groups	33,0%	16,1%	50,9%	100,0%
	Nearsighted	Count	14	2	16	32
		% within Eye sight groups	43,8%	6,2%	50,0%	100,0%
	Farsighted	Count	9	3	8	20
		% within Eye sight groups	45,0%	15,0%	40,0%	100,0%
Total		Count	60	23	81	164
		% within Eye sight groups	36,6%	14,0%	49,4%	100,0%

Symmetric Measures

		Value	Approx. Sig
Nominal by Nominal	Phi	,143	,500
	Cramer's V	,101	,500
N of Valid Cases		164	

10.2: Eyesight →nausea

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Eye sight groups * I felt nauseous	165	88,2%	22	11,8%	187	100,0%

Eye sight groups * I felt nauseous Crosstabulation

			I felt nauseous			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Eye sight groups	Normal	Count	20	17	75	112
		% within Eye sight groups	17,9%	15,2%	67,0%	100,0%
	Nearsighted	Count	10	2	20	32
		% within Eye sight groups	31,2%	6,2%	62,5%	100,0%
	Farsighted	Count	7	0	14	21
		% within Eye sight groups	33,3%	0,0%	66,7%	100,0%
Total		Count	37	19	109	165
		% within Eye sight groups	22,4%	11,5%	66,1%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,218	,098
	Cramer's V	,154	,098
N of Valid Cases		165	

10.3: Eyesight → balance

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Eye sight groups * Lost balance	165	88,2%	22	11,8%	187	100,0%

Eye sight groups * Lost balance Crosstabulation

			Lost balance			Total
			I agree/ partly agree	I am neutral	I partly disagree/disagree	
Eye sight groups	Normal	Count	43	14	55	112
		% within Eye sight groups	38,4%	12,5%	49,1%	100,0%
	Nearsighted	Count	11	4	17	32
		% within Eye sight groups	34,4%	12,5%	53,1%	100,0%
	Farsighted	Count	7	1	13	21
		% within Eye sight groups	33,3%	4,8%	61,9%	100,0%
Total		Count	61	19	85	165
		% within Eye sight groups	37,0%	11,5%	51,5%	100,0%

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	,102	,785
	Cramer's V	,072	,785
N of Valid Cases		165	