Investigating Motion Sickness in Racing Simulators using Virtual Reality and a Motion Platform

ANDREAS LANGÅKER
STIAN NGO

SUPERVISORS
Associate Professor Ghislain Maurice Norbert Isabwe
Associate Professor Morgan Konnestad

University of Agder, 2021
Faculty of Engineering and Science
Department of Information and communication technology

Acknowledgements

First, thanks to our supervisors, Ghislain Maurice Norbert Isabwe and Morgan Konnestad. Your guidance, patience, support and critique has really made us perform our best. We would also like to give our appreciation towards the department for giving us the funds to purchase the motion platform. In that regard, we give our thanks to Wijnand Derks and GforceFactory for excellent customer service. Special thanks goes to our participants, even those only managed to attend once or twice. Appropriate thanks goes without saying to those who suffered intensely from motion sickness and still finished all the scenarios.

The team met during the master period and found an interesting dynamic between. Many arguments have been held, some loud, some with acceptable volume. However, in the end we managed to deliver something we both can be proud of. We would like to a thanks to each other and good luck in future endeavors.

Andreas Langåker,
Stian Ngo,
Grimstad, 2021

Abstract

Motion sickness has been a downside of virtual reality since its beginning. According to the "Sensory conflict" theory, simulation sickness and cybersickness often occurs due to the feeling of self-motion. This thesis aimed to investigate if a motion platform could mitigate simulation sickness. By using commercial available motion platform and virtual reality headset, the experiment had three conditions, one without any added motion, one with motion and the last with increased motion. Participants were put in a complete racing set to drive an Edge 6D motion simulator in Asseto Corsa. The participants drove a high-speed car for 10 min on the. Other research points included game engagement, measured with the Game engagement questionnaire. Our findings indicates that adding simulated motion to virtual reality interactions can have a positive effect towards reducing simulation sickness. Added motion can also improve game engagement. However, further investigations should focus on specific parameters that causes simulation sickness. This investigative research presented potentials for further improvements for combining virtual reality with a motion platform for car/racing training.

Glossary

HMD	Head Mounted Display	Chapter 3.3.4
VR	Virtual Reality	Chapter 2.2
FMS	Fast motion sickness scale	Chapter 2.4
SSQ	Simulator sickness questionnaire	Chapter 2.4
GEQ	Game engagement questionnaire	Chapter 2.4
CS	Cybersickness	Chapter 2.3
SS	Simulator sickness	Chapter 2.3
DOF	Degrees of Freedom	Chapter 3.6
CSQ	Cybersickness Questionnaire	Chapter 2.4
CAD	Computer-aided design	Chapter 3.1
DR	Driving simulator	
FOV	Field of view	
MS	Motion sickness	Chapter 2.3
JOSC	Joyfullness scale	
MISC	Misery scale	
VR-HMD	Virtual Reality - Head Mounted Display	
POMS	Probability of MS score	

Contents

Chapter 1

Motivation and Problem statement

1.1 Motivation

Virtual reality is a developing and exciting marked with technologies that brings entertainment to another level of enjoyment. As of 2020, a report by Grand view research notes that the global virtual reality marked size will was valued at 15.81 billion USD and is expected to grow 18% from 2021 to 2028[54]. The growth is not only present in home-use for consumers, it is also being adopted in commercial use such a showcasing. The health sector is also reported to have a growth from 2021 to 2028.
The initial thesis started with an open inquiry from Align racing, the formula student team of University of Agder (UiA). They asked for some master students to research using a racing-simulator for training their drivers. This initially intrigued us and we eventually decided for this to be our master. The simulation would be used on their drivers as a supplement to their ordinary training. The simulation would allow drivers to conduct mass training in a safe and risk free environment. With this tool, drivers can train in more volume and higher speeds then they would do on the parking lot. However, virtual reality(VR) comes with the potential for cybersickness. We want to see if this can be limited. The sensory conflict theory suggests that a disconnect between motion seen and felt can induce cybersickness [40]. We want to introduce a high fidelity motion platform to adequately mimic motion seen in the virtual reality - head mounted display (VR-HMD). This in turn may reduce cybersickness. However as the project evolved, the prospect of measuring learning with a racing-platform became a challenge. Since the project already had acquired a motion platform, the research focus changed to studying motion sickness/cybersickness using VR and a racing-motion-platform. Before focusing on the learning aspect, motion sickness and cybersickness needed to be addressed and researched.

1.2 Problem statement

Training to drive a race car demands a lot of financial and human resources, making it hard for small/poor organizations/companies to do as often as they want. It also requires that the specific vehicle is ready and not into repair or occupied. While driving in a simulation, as stated above, would be a far less expensive investment. Simulators using VR-HMD or LCD screens have been recorded to provide mild to severe afflictions, which can be organized simulator sickness and cybersickness. If there could be a way to minimize this effect of driving a simulation, it would appear a more appealing choice for training drivers or use it in educational settings like learning to drive different vehicles.

1.3 Research Questions

As stated in the problem statement chapter 1.2 and our motivation chapter 1.1 two research question was conducted as a result:

- Is it possible to reduce simulator sickness in virtual reality racing simulators using simulated motion?

  To what degree, if any, does simulated motion contribute to reducing simulator sickness in virtual reality racing simulation?

- Is there a correlation between game engagement and simulation sickness?

1.3.1 Limitation

This will be an investigative research experiment with the aims of creating a research environment to investigate physiological (motion sickness) and psychological (game engagement) parameters using commercial virtual reality headset and a motion platform. Lastly, we will conduct a brief inquiry regarding public views on driving simulators in an educational setting.

Chapter 2

State of the art

In this chapter we will highlight the use of VR correlated to driving/racing training. We will also look into Cybersickness, motion sickness and ways to limit this affliction.

2.1 Simulators and learning

One of the earlier places to adopt simulators is in pilot training for air-crafts[12]. BP et al. [12] presents that the simulators are applied from development, production to training for both pilots and ground crew. Driving schools and motor-sport teams are other field where simulators are being used. Formula 1 racing teams, such as Redbull [53], are known to use racing simulators. Additionally, a racing sport club in Norway [23], is using simulators to train their drivers both for e-sports and real life racing. A study tested the effects of racing-simulators by correlating simulator laps with real life laps[28]. They tested this by having drivers drive the same tracks in a simulator and in real life, and then compare the results. The results suggests that faster laps in a simulation does indeed correlate with faster laps in the real world. "... we provided a validation study of a race car simulator showing that drivers fastest lap times in the simulator correlated well with the fastest lap times during race events on the real-world tracks, a significant effect" [28, p. 13]. A figure from 2010 provided by the Dutch Institute for Road Safety Research (SWOV) fact sheet, estimated that the country had 150 driving simulators in driving schools [66]. Researcher conducted an investigation regarding the simulators mentioned in the SWOV fact sheet, and their effects. The results unveiled that those who used simulator in their driving education had a slightly higher chance of passing their driving exam compared to the national average [72]. Additionally, regarding driving education, Abele and Møller [1] demonstrated that a driving simulator could be used to improve hazard perception. Sixty participants were divided into two equal groups. One group had prior hazard perception training using the simulator before their test-drive, while the other group drove the test-drive without prior training. The group which had prior training performed better. Abele and Møller [1, p. 12] mentions that a simulator can be of great for teaching basic skills in a safe environment. Moving on from basic skills, a simulator can also be used for practising scenarios[65]. Ihemedu-Steinke et al. [31] created a virtual environment where one could operate a vehicle in hazardous and dangerous driving related scenarios. Compared to testing these scenarios in a real life driving site, it is much cheaper to do so in VR [31]. While practising scenarios, simulators also have the potential of improved feedback. Depending on the simulator, users and instructors can get different perspective and data which can be used to review a session later on [4]. The simulator in Walch et al. [69, p. 153] recorded head movement, speed and other activities such as signaling, lane changing, acceleration and breaking. Generally, feedback is also easier to transmit in a simulator, where driving can be paused and restarted with ease [1].
Backlund et al. [4] built a simulator where the virtual environment was projected using

projectors connected to computers (See figure 2.1). They tested this simulator on students who reported back with positive results. However more importantly, the study asked for the opinion of driving instructors as well. The instructors appraised the possibility of simulating dangerous and critical scenarios. The results of the paper suggests that driving simulators can be used to enhance the learning experience in driving education.

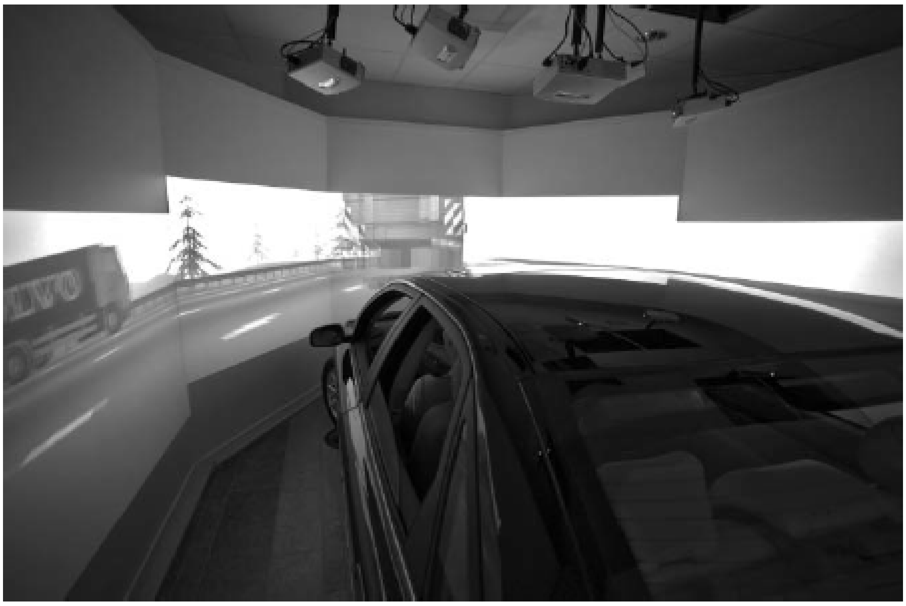


Figure 2.1: Car-simulator visualised by projectors, operated from inside a real car [4, p. 153]

.

Prohn and Herbig" [51] conducted a research project to explore the usefulness of simulator-based training on ambulance drivers. Two different simulators where used, only one had motion, and both used LCD displays (Not VR-HMD). The participants evaluated the experiment three times. Once, immediately after completion and again after one/two months, and finally after six months. In general, the participants reactions where positive. The second evaluation however, unveiled lower overall scores as figure 2.2 shows. It is worth noting that less and less participants are answering the questionnaire over time.

descriptive statistics for reaction to training.

scale of training evaluation	range	directly after training (N = 166)		one to two months after training (N = 151)		six months after training (N = 44)	
		M	SD	M	SD	M	SD
contents	[1, 5]	4.36	0.68	/	/	/	/
trainer	[1, 5]	4.66	0.59	/	/	/	/
organization	[1, 5]	4.46	0.54	/	/	/	/
applicability	[1, 5]	4.18	0.81	3.50	0.96	3.51	0.91
recommendation	[1, 5]	4.54	0.91	3.78	1.20	3.89	1.15
grade*	[1, 6]	1.76	0.92	2.42	1.02	2.42	1.05

Figure 2.2: The participants own evaluation of the experience, directly and up to six months later [51, p. 6]

.

2.1.1 Choosing the Simulator Software

A Web-article from Formula 1[6] describe a team using simulators to train their drivers. However, this simulator is not stated to use VR. The team uses simulators to simulate different parameters of a virtual car before installing them on the real car. Drivers will also spend time in the simulator to study the track. Exactly what simulator software they are using is not known. Many professionals however, have stated that they play “iRacing”,“rFactor” in their free-time. Asseto Corsa is also hugely recommended because of its physics and the amount of customization possible [43][44].

2.1.2 Simulator rigs

When it comes to the development of simulation rigs, it had its roots in flight simulators applied since the early 1900s. The launched a high fidelity driving simulator in the early 1980s by Daimler-Benz in Germany [20] it got broad interests throughout the world with driving simulators. Driving simulators are there is little evidence supporting its validity despite frequent use [74]. For most, fidelity has not seemed to be considered. According to Wynne, Beanland, and Salmon [74] systematic review of driving simulator validation studies, the relationship between simulators fidelity and validity was not as straightforward as expected. That is not all high-fidelity simulators were able to achieve validity. Some simulators were able to achieve validity on some measures while not on others. Where almost half was scored as fidelity score of medium.[74]. According to Lucas et al. [41], you can reduce simulation sickness with the simulation rig with the right vibration. There is a need for motion in motion platforms to have a higher focus on motion platform engines that are precise movement instead of strong. According to a blog post at Actuonix Motion Devices [2], using servo over linear makes the platform stop as soon it doesn’t get new orders and moves to the planned location. As the servo is "smart" since they save the position, they will move to the area on the cylinder it is supposed to even if the system is silent.

2.2 Virtual Reality - HMD

Looking up "Virtual Reality" in the Merriam-Webster and the Oxford English Dictionary, produces these definitions:

"an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one’s actions partially determine what happens in the environment." Merriam-Webster [46]

"A computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way by a person, esp. by means of responsive hardware such as a visor with screen or gloves with sensors; such environments or the associated technology as a medium of activity or field of study; cyberspace." Oxford-English-Dictionary [50]

From these definitions, we can safely say that VR is an artificial environment which can be interacted with. As per the definition, VR can be experienced through *responsive hardware*. Virtual Reality-head mounted displays (VR-HMD) is one type of hardware which can be used to experience VR [34]. Jason Jerald [34, p. 32] explains the VR-HMD as a display that is attached to, and moves with the head. In addition to this, by using appropriate ear-phones the user can block out real world sounds with virtual sounds, creating a highly immersive virtual environment.

2.2.1 Tracking

There are two main methods of tracking in modern VR-HMDs; inside-out and outside-in. Inside-out positional tracking relies on internal cameras in the head mounted display(HMD) to calculate how its position has changed relative to the environment. The Oculus rift S uses inside-out tracking where cameras on the HMD takes images which then are internally processed to generate a 3D map of the room [3]. Inertial measurement units inside the headset and controllers are also employed to track movements. The controllers are additionally emitting infra red signals which are picked up by the headset taking in use elements of outside-in tracking. Another variant of inside-out is found in lighthouses or base-stations used in the HTC VIVE series and Valve index VR. Infrared lights are emitted from the base-stations which are then picked up by the HMD and controllers. Notably, the base-stations only create signals and does not communicate with the computer [7].

Figure 2.3: Oculus Rift S.

Outside-in tracking uses external cameras to be pointed at the HMD. The original Oculus rifts HMD and controllers emits infrared lights which would be picked up by an external Oculus-sensor [48].

Ihemedu-Steinke et al. [31] developed a virtual reality driving simulator based on Head-Mounted displays in Unity Engine. The simulator was used to access users behaviour in a hazardous driving environments, "The most effective way to understand how drivers master situations which could lead to an accident would be to place them in that same situation." [31, p. 402]. However, placing drivers in a real life situation is too hazardous, while testing in a crash site environment is both expensive and time consuming. Ihemedu-Steinke et al. [31] explain that there currently are driving simulators used in the automotive industry, most of them are using 2D screens. They add that replacing the 2D screens with HMD's would increase the overall immersion and realism. Ihemedu-Steinke et al. [31, p. 402] believes that this level of immersion is key for achieving realistic reactions from test-drivers. Their findings points out that HMD's used with a driving simulator

Figure 2.4: The predecessor of the Oculus Rift S. This Oculus Rift uses outside-in tracking technology that tracks infra red signals from the Oculus Sensor.

could create highly immersive experiences. However, further explanation points out that realistic high quality visual assets are important to achieve a level of realism. Visual assets concerns both the exteriors and interior of the car, along with the environment which the car drives in such as traffic lights. Pedestrians, cars and other moving elements should also have realistic animation and behaviour.

Ihemedu-Steinke et al. [31] concludes that using a driving simulator (DR) with VR could be advantageous for testing in the automotive industry. Especially testing conceptual products that are not yet physically produced. Despite the advantages with a higher potential for immersion, there are still challenges that arise with this technology. Their goal was to make the simulation as near-realism as possible. Firstly, one could observe pixels in the headset, which can have negative effects on the immersion. Next, there were challenges to make the simulator *feel* like driving a real car. Mainly the problem was connected to that motion in the simulator was not felt in real life. Motions such as braking, turning or accelerating. Another problem related to motion is if there is a delay between an action in the real world and the game. These inconsistencies in motion correlates to the next challenge which concerns motion sickness. Lastly, they touched on the importance of sound. The simulator needs to realistically replicate sounds from the car and the surrounding environment. Relatively expensive equipment must also be purchased to fully take advantage of VR:

- Powerful Computer
- Virtual Reality Headset
- Steering wheel and pedals with forced- and Haptic feedback
- Motion platform is optional, however might be effective in preventing motion sickness
- Development of the VR application

Walch et al. [69] compared the user experience regarding playing a driving simulation with a triple screen setup and VR-HMD. One of the main measures were cybersickness and immersion. The study recruited 20 participants that would play the simulation (Project Cars) with both setups. After each condition, participants were handed questionnaires (See figure 2.5) to fill out. These questionnaires would measure simulation sickness, affective state, immersion, presence and intrinsic motivation. Three screens of 40 inches each was placed in an arch which afforded the player a field of view (FOV) of approximately $135°$. The VR setup consisted of the HTC vive headset which has a FOV of $110°$ and a combined resolution of 2160 X 1200 pixels. In both setups, participants would use the same steering-wheel (Fanatec), pedals (Fanatec) and racing-seat (RaceRoom). Even though that the VR caused more discomfort, it was generally the preferred over the triple-screen monitor setup. It is worth noting that participants had no resting period between the conditions. And finally, the participants had to answer 5 questionnaires in total, which Walch et al. [69] discussed could cause survey fatigue, which might decrease the quality or accuracy of the responses.

Area of measurement	Questionnaires
Simulation sickness	SSQ - Simulator sickness questionnaire
Affective state	SAM - Self assessment manikin
Immersion	IEQ - Immersive experience questionnaire
Presence	PQ - Presence Questionnaire
Intrinsic Motivation	Interest/Enjoyment subscale of Intrinsic motivation inventory (IMI)

Figure 2.5: The Questionnaires used in Walch et al. [69]

2.3 Simulator sickness and Cybersickness

In chapter 2.1, simulators was appraised for their practicality and versatility in both an educational- and recreational environment [31][12]. However, simulators are prone to cause discomforting afflictions such as simulation sickness and cybersickness [31][69]. Simulators using VR-HMD or LCD screens have been recorded to provide mild to serious afflictions which can be organized simulator sickness and cybersickness. Gavgani et al. [25] conducted an experiment where participants experienced cybersickness inducing stimuli. The participants were tested over a period of time after the stimuli, and findings points out that symptoms may last longer than three hours. Cybersickness is regarded as a subset of motion sickness [25] and therefore shares many of the same symptoms found in simulation sickness as well. Nausea, headache, cold sweats, eye strain or a sense of general discomfort are some of the shared common symptoms. Despite the similarities, it is important to note that these are different illnesses with their own symptom groups [17][52]. Unlike cybersickness(CS) and simulation sickness(SS), motion sickness(MS) have fewer symptoms regarding the oculomotor nerve [39]. Additionally, Stanney, Kennedy, and Drexler [61] notes that the signs for vomiting or retching are rarer in cybersickness compared to the other illnesses.
Dużmańska and Strojny [22] conducted an empirical review with the focus on simulation sickness. One section regarded persistence of simulation sickness. The results presents that simulation sickness may last up to 24 hours after exposure. How ill a person feels after an experiment and how long the stimuli lasted might also affect how long the sickness persists. Lighter symptoms may dissipate faster than severe ones. Another article in Dużmańska and Strojny [22] reports suggests that symptoms might worsen some time after exposure.

2.3.1 Sensory conflict theory

Davis, Nesbitt, and Nalivaiko [17] points out that CS often occur due to the feeling of self-motion. Self-motion is when a person is sitting still in the real world, but the virtual world is moving. Being motionless in real life while being in motion in a virtual environment can cause the sensation of self-motion and thus discomfort. SS however, is often caused by discrepancies between what the user expects and what is felt [17]. Both these causes can be seen as sensory mismatches. Both examples are instances where the person is expecting certain movements while not receiving it. Rebenitsch and Owen [52] explain that:

"Sensory mismatch is often the explanation as to why vection, the perception of the world moving away from the user, is strongly correlated with cybersickness symptoms." [52, p. 105].

Sensory mismatch can therefore be seen as cause for both CS and MS.Sensory mismatch can also be referred to as The sensory conflict theory and is the oldest and most accepted theory [40][52].LaViola Jr [40] specifies further that the expected stimulus is based on a persons experience:

"These sensory conflicts arise when the sensory information is not the stimulus that the subject expected based on his/her experience." LaViola Jr [40, p. 50].

In medical terms, the sensory conflict theory regards contrary stimuli between the vestibular sense and the visual sense [40]. In short, the vestibular system is canals in the inner ear filled with fluids. Head rotation or movements will force these fluids to move through the canals that corresponds with said movement [18]. As the fluid moves to the designated areas, signals are then transferred to other organs in the ear. In the end, the rotation and movements would have translated into sensations of acceleration, tilting or gravity [18]. An experiment investigated cybersickness by having participants ride a roller coaster in VR [25], without any real life motion. They argue that the CS symptoms felt by the participants is likely due to sensory visual-vestibular conflict, in other words; the sensory conflict theory:

"while rich imagery informed the brain about dramatic linear and angular accelerations, this information was not matched by afferent input from the vestibular and proprioceptive systems of the stationary subject." Gavgani et al. [25, p. 46].

Ng, Chan, and Lau [47] conducted an experiment to investigate the sensory conflict theory using a 3 degrees of freedom motion platform and a VR-HMD as display. A chair was strapped to a motion platform that provided 3 degrees of freedom. When seated in the chair using the VR-HMD, the participant would be in a virtual kitchen environment. The person had a joystick which would rotate the platform (if motion was activated). There was three conditions that users could experience:

- Stationary: The user only receives visual stimuli, i,e from the VR headset. When the participant move the joystick, only the visual image would be moved.
- Synchronous: The visuals moves with the motion of the platform.
- Self-referenced: An algorithm that convert every movement from the motion platform and reverse it in the view-port, making it so that the surface is always horizontally flat (Similar to what the motion compensation does (See chapter 3.4.3)).

A dataset of 12 participant was gathered and they found that the conditions with motion preformed better than stationary. The Joyfullness scale (JOSC) scale saw an increase in both conditions with motions, while the Misery scale (MISC) and Simulator sickness questionnaire(SSQ) saw a decrease (See figure 2.6 for full results).

The postural instability is an alternative to the sensory conflict theory Stoffregen and Riccio [63]. Riccio and Stoffregen [55] developed this theory and argues that prolonged postural instability is the cause of motion sickness. The essence of the postural instability theory is that people want to be postural stable in an environment [55]. Adding further

Table 4
Mean and standard deviation of various ratings and scores in three conditions.

	Misery		Joyfulness		SSQ-Total		SSQ-Nausea		SSQ-Oculomotor		SSQ-Disorientation	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Stationary	3.57	1.69	5.21	2.95	48.31	33.27	46.91	36.02	28.43	18.06	59.16	45.57
Synchronous	1.06	1.02	7.64	1.50	30.23	43.15	21.86	37.16	23.69	28.30	37.12	56.83
Self-referenced	1.90	1.40	6.90	1.82	40.36	35.26	37.37	33.63	28.74	24.69	42.92	42.24

Figure 2.6: The results of Ng, Chan, and Lau [47, p. 4] regarding the MISC, JOSC and SSQ.

that postural instability is necessary to produce symptoms and that the severity will scale according to the duration of the instability. According to this theory, people may experience forms of motion sickness if one is postural unstable in a situation, for example on a boat. If a person would learn to stabilise himself with the boat, then they would be stable. However, if a person resist the motion of the boat, then this would cause motion sickness [55].

2.3.2 Limiting Cybersickness

VR adaption suggests that with multiple uses, over time a user might get used to a VR environment and experience less simulator sickness or cybersickness symptoms [22]. As briefly mentioned in the section above, Gavgani et al. [25] conducted an experiment where participants rode a roller coaster in VR for 3 consecutive days (15 min per ride). Out of 14 volunteers, only 1 managed to complete the full 15 minute ride for all three days. The remaining would prematurely terminate the ride due to nausea. Compared to the first day, there was no change in mean ride time on the second time. However, the mean ride-time raised considerably on the third day with 66%. Even though the maximum nausea levels were relatively similar between the three days, the speed of nausea development was decreased. Gavgani et al. [25] concludes that repetitive exposure to VR can result in desensitization over time.

Yildirim [75] conducted an experience to document the effects of cybersickness using commercial VR-HMDs (HTC Vive, Oculus Rift CV1). One of the experiments had thirty-six participants play the racing game, Asseto Corsa. Participants where randomly selected a playing device, either an HTC Vive, desktop or Oculus Rift. All participants played to game using a Xbox controller. After playing, the participants would answer an online questionnaire containing the SSQ. The results reviled that participants that played with VR-HMDs experienced more symptoms regarding Cybersickness. Interestingly, the symptoms varied between the HMDs where Vive users reported more severe nausea symptoms whereas Oculus Rift reported more oculomotor symptoms. Notably, the directed play time was only 10 minutes, which implies that the time for symptoms to appear is relatively short. Similarly, Malone and Brünken [42] conducted a similar study to investigate the difference between a triple screen monitor setup and a VR-HMD. This experiment however, used an Oculus Rift Development Kit 2, which is older (2014) than the HTC vive (2016). Their participants completed 6 conditions lasting approximately 3 minutes each with 30 seconds breaks between them. 42 out of 80 participants completed the HMD condition while the remainder experienced the triple screen condition. The context of use was a driving simulator where participants had to avoid hazardous collisions. Findings suggested that VR had a potential for more virtual presence due to an objective measure of "head sway". However, they also conducted a subjective measure using a questionnaire and found little difference between the two conditions.

2.3.3 Symptom group explanations

According to P. Bockelman's study, symptoms of cybersickness are disorientation, dizziness, eyestrain, headache, sweating, fatigue, stomach discomfort, nausea/stomach discomfort, vertigo, blurred vision[10]. The simulation sickness questionnaire[36] divides these symptoms into three clusters: nausea, oculomotor, and disorientation. Their reason for doing this is that A.C. Bittner, J.C. Guignard made similar clusters of the symptoms in their paper evaluating motion sickness incidence regarding seasickness[9].

Nausea

Nausea was originally used as a definition of signs and symptoms of seasickness[5]. And according to Dorland's Illustrated Medical Dictionary, nausea is "an unpleasant sensation, vaguely referred to the epigastrium and abdomen, and often culminating in vomiting"[19]. Kennedy defined nausea as a cluster of symptoms that included general discomfort, increased salivation, sweating, feeling nausea, difficulty concentrating, stomach awareness, and burping[36].

Oculomotor

Definition of oculomotor according to Merriam Webster definition is "moving or tending to move the eyeball" or "of or relating to the oculomotor nerve" [45]. The oculomotor nerve, also known in medical term as the third cranial nerve(CN III), and innervation to the pupil, lens upper eyelid, and eye muscles that allow for visual tracking and gaze fixation[35] Kennedy defined oculomotor as a cluster of symptoms that included general discomfort, fatigue, headache, eye strain, difficulty focusing, difficulty concentrating, and blurred vision[36].

Disorientation

Holmes defined visual disorientation as an affection of the power of localizing the position in space and distance of objects by sight alone. Holmes patients were demonstrated by their inability to touch objects accurately held in their field of vision, the failure to recognize the relative positions of two entities, and difficulty judging distances or recognizing the size of objects by sight alone.[30] Kennedy defined disorientation as a cluster of symptoms that included difficulty focusing, nausea, fullness of head, blurred vision, dizziness, and vertigo[36].

2.4 Evaluation Methods

The simulator sickness questionnaire (SSQ) [36] is a popular questionnaire for measuring simulator sickness (SS) and cybersickness (CS)[37], with over 3000 citations on the original paper [8]. The SSQ is an altered version of the Pensacola Motion Sickness Questionnaire (MSQ), and was originally developed in the 1990s for military flight simulators. Kennedy et al. [36] needed a questionnaire which distinguished motion sickness from simulator sickness. The SSQ measures in 3 symptom categories: nausea, oculomotor and disorientation.
There are other proven questionnaires for cybersickness, such as the Virtual Reality Sickness Questionnaire (VRSQ)[38] and the Cybersickness Questionnaire (CSQ). Regarding the VRSQ, Kim et al. [38, p. 70] argues that the SSQ contains elements which are unnecessary to measure in a virtual environment. Essentially, the SSQ takes in account that motion sickness can originate from real life movement, such as a motion platform. Kim et al. [38] explains this as "SSQ indicates motion sickness due to the simulators, including inertial motions;". The CSQ also attempts to refine the SSQ to find the elements which

targets Cybersickness the most. They argue that some symptoms such as sweating may be caused by other factors, such as physical effort [57, p. 2]. Moving further with the SSQ, one can debate if the questionnaire should be administered both before and after stimuli exposure. On the one hand, applying the SSQ before an exposure would capture if the participant felt off their usual state of fitness/well being. On the other hand, Young, Adelstein, and Ellis [76] found that administering the SSQ before a stimuli would increased the scores a fair amount. Young et al. concludes that participants could be biased through demand characteristics. Keshavarz and Hecht [37] briefed three groups differently before being exposed to a motion sickness inducing stimuli. One group was told that the experience would be causing motion sickness, another group was told that the experiment would bring joy while the last group had a neutral briefing. The results showed no significant distinction between the three groups. Keshavarz and Hecht did not have a clear explanation why their results disputed with Young et al.Bimberg, Weissker, and Kulik [8] reviewed the SSQ and came up with guidelines and suggestions in terms of applying the SSQ. They argue that despite the examples of demand characteristics, it is still fair to apply the SSQ both before and after stimuli. This is especially the case for experiments where the SSQ would have to be answered multiple times anyways, such as a within-subject design [8].

Keshavarz and Hecht [37] presents the Fast motion sickness scale (FMS) as an application which could be used while undergoing stimuli. Questionnaires such as the aforementioned SSQ and VRSQ are designed to be administered after stimuli. The FMS is designed to be a fast and simple method to evaluate MS on a frequent scale. Before a stimuli, the participant is informed of motion sickness symptoms. While under stimuli, the observer will ask each minute for the participant to rate their MS on a point-scale of 20. Since the FMS is to be administered in relatively rapid successions, makes it useful for capturing the development of MS within a participant during the exercise. Keshavarz and Hecht [37] ads that if participants are reporting high numbers (around 14), then to avoid further sickness or vomiting, the researchers may ask the participant if they want to stop, A challenge with the FMS regards the participants own interpretation of their motion sickness. Participants may take into account other MS-unrelated sensations [37].
Keshavarz and Hecht [37] used both SSQ and FMS in their study and compared the two results to validate the FMS. They found a strong correlation between the FMS and SSQ-total scores. Further correlation was also found within the SSQ's sub-symptoms. Somrak, Pogačnik, and Guna [60] conducted a similar study to compare the FMS and SSQ, among other. The FMS proved to have a strong correlation to the SSQ total scores and SSQ Nausea scores. However the weakest correlation was with the Oculomotor subscore, which was expected since the FMS does not cover oculomotor symptoms [60].

Gavgani et al. [25] used a similar scale but did not specify it with any name. Similarly to the FMS, participants were asked to rate their level of motion sickness every minute. Their scale ranged from 0 (no effect) to 10 (Just about to vomit). The MISC and JOSC are likewise similar scales which are used in motion sickness investigations [47]. Both of theses scales are applied each minute. The MISC is a 11-points scale (0-10), where 0 is "no problem" and 10 is "on the verge of vomiting". The JOSC uses a similar rating from 0-10, where 0 is "Having a bad time" and 10 is "Having a pleasant time".

Weech, Kenny, and Barnett-Cowan [71] conducted a wast review regarding the relationship between presence and cybersickness. They present that the most popular form for measuring presence is to use questionnaires, such as the "Presence Questionnaire." However, Weech, Kenny, and Barnett-Cowan [71, p. 3] also acknowledge that self-reporting presence with questionnaires has faced much criticism. Another measuring method is the use of "Physiological measurements." Stress, for example, can be an indicator of presence. Stress can be measured with sweating, heart rate, and other responses.

2.4.1 Measuring engagement

Brockmyer et al. [13] developed the game engagement questionnaire (GEQ) to measure engagement in video games. The questionnaire consist of 19 items and is divided into areas of measurements comprised of absorption, flow, immersion and presence (See table 2.4.2). It was originally developed to measure impact of video games, especially violent ones. Other uses have been seen in racing games [64], including racing games using VR [16].

2.4.2 Describing the measurements

Immersion

Brockmyer et al. [13] explains immersion in games as being engaged in the activity. Adding that it could also be a feeling of being a part of the game environment. Similarly, [73] describes immersion as an experience of being enveloped in an environment where one can also interact with it. The environment also needs to constantly provide stimuli to the user [73]. Additionally, Witmer and Singer [73] notes that immersion is correlated with presence: "A virtual environment that produces a greater sense of immersion will produce higher levels of presence." [73, p. 277]. To increase the level of immersion, one can attempt to remove any distractions that would draw attention from the virtual environment. Other factors such as the feeling of control of movement [73].

Presence

Witmer and Singer [73] developed the presence questionnaire (PQ) to measure presence in a virtual environment. They define presence as an experience of being situated in one environment while being physically situated in another. There are also different degrees of presence, where the attention and focus of the participant is determining on how involved a participant will be in an environment [73]. A similar definition is presented by Brockmyer et al. [13], where presence is the sensation of being inside a virtual environment, while operating in a normal state of consciousness.

Flow

Brockmyer et al. [13, p. 625] describes flow as a intrinsically rewarding sensation of enjoyment during an activity where skill and challenge is sufficiently balanced. Specific tasks during the activity along with meaning-full will increase the chances for achieving flow [13]. Some characteristics of flow are time distortion, feeling of control [13].

Absorption

Brockmyer et al. [13] refers to Irwin [33, p. 158] and presents absorption as term where a person is totally involved and committed to an experience or the "attentional object". Sapp [56, p. 39] describes absorption in context of hypnosis, but presents the term as someone who is open and ready for "mental and emotional involvement". Adding that the person is also unaffected by distractions while absorbed in the experience.

Absorption	Immersion	Flow	Presence
I feel scared	I really get into the game	I don't answer when someone talks to me	Things seem to happen automatically
I lose track of where i am		I can't tell I'm getting tired	My thoughts go fast
I feel different		If someone talks to me I don't hear them	I play longer than i meant to
Time seems to stand still or stop		I feel like I can't stop playing	I lose track of time
I feel spaced out		The game feels real	
		I get wound up	
		Playing seems automatic	
		I play without thinking how to play	
		Playing makes me feel calm	

Table 2.1: All the questions from the SSQ categorized into the four measurements.

Chapter 3

Racing Simulator Experimental Setup

3.1 Align Racing Testbed

Align racing wanted a VR training simulator. Where they could train their drivers with their cars (See chapter 1.1).
Align Racing gave us access to a 3D model of their new racing car which was still in development. The reason for this was to have a vehicle that was known to the personnel at Align racing. The drivers of this car could give feedback on how the motion platform and the car acted compare to the actual vehicle. Making a close copy of a real example and, in the same way, created a simulation for the drivers at Align Racing.

Figure 3.2 shows the pipeline for the car development in red, and what program was used in the car development. The model from Align Racing was originally created in a Computer-aided design (CAD). The CAD model was converted into an FBX file and then imported into 3DMax, a 3D modeling program (See chapter 3.4.2). Unnecessary element such as the driver position marker, a lot of component that is under the car and duplicates was removed. A lot of the inner part of the motors which was not visible for the participant, while driving, was removed as well. To make this model work inside the Asseto Corsas development tools the cars hierarchy had to be reworked (See chapter 3.4.1).

Figure 3.1: Align Racing car i Content Manager in full chromium material
.

To simulate the car new car inside Asseto Corsa as intended, parts needed to be allocated inside the program. This was done by placing each part under its own dedicated group, for instance, every part that belongs to the brake in the brake group. After that the car model is imported into ksEditor, one of Asseto Corsas development tools, where you can convert the FBX file from 3DMax, to a KN5, which is an Assetto Corsa 3D Object file type. This tool was primarily used to convert the file type to be readable by the Content Manager, an alternative launcher to Assetto Corsa. From Content Manager, a showroom was available were small visual changes could be made. Config files could be unpack and packed using Content Manager. The cars configs files is where one would edit any possible car stats, such as weight, horsepower or breaking-strength.
However, due to the difficulty of controlling the vehicle and extra workload for fine-tuning, the car ceased development. The car was replaced with a vehicle that came with the game, which was more controllable and manageable to drive.

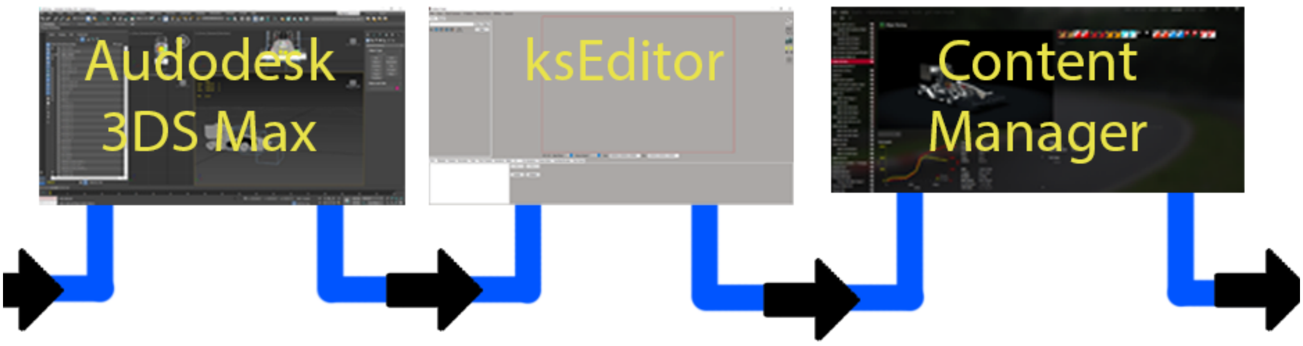


Figure 3.2: Development pipeline of Align Racing Car
.

3.2 Car Racing Simulator System Components

The simulation ran in Asseto Corsa (See chapter 3.4.1), where the Vive Cosmos Elite Virtual Reality headset (See chapter 3.3.4) was used as display. The participant will sit in the motion platform, Edge 6D Motion Simulation (See chapter 3.3.1). The platform has 6 degrees of freedom and will in theory move the participant accordingly to the simulation, essentially mirroring the movements in the game. The participant used the Thrustmaster T300RS (See chapter 3.3.3) steering wheel and pedals as controls as seen in figure 3.3.
The Vive Cosmos Elite sends the head coordinates into Asseto Corsa using SteamVR [62], then returns the visuals and movemements back into the HMD as figure 3.3 shows. After the pilot testing (See chapter 3.8.4), the setup was changed, adding software to SteamVR that cancels out the movement of the motion platform, see chapter 3.4.3.

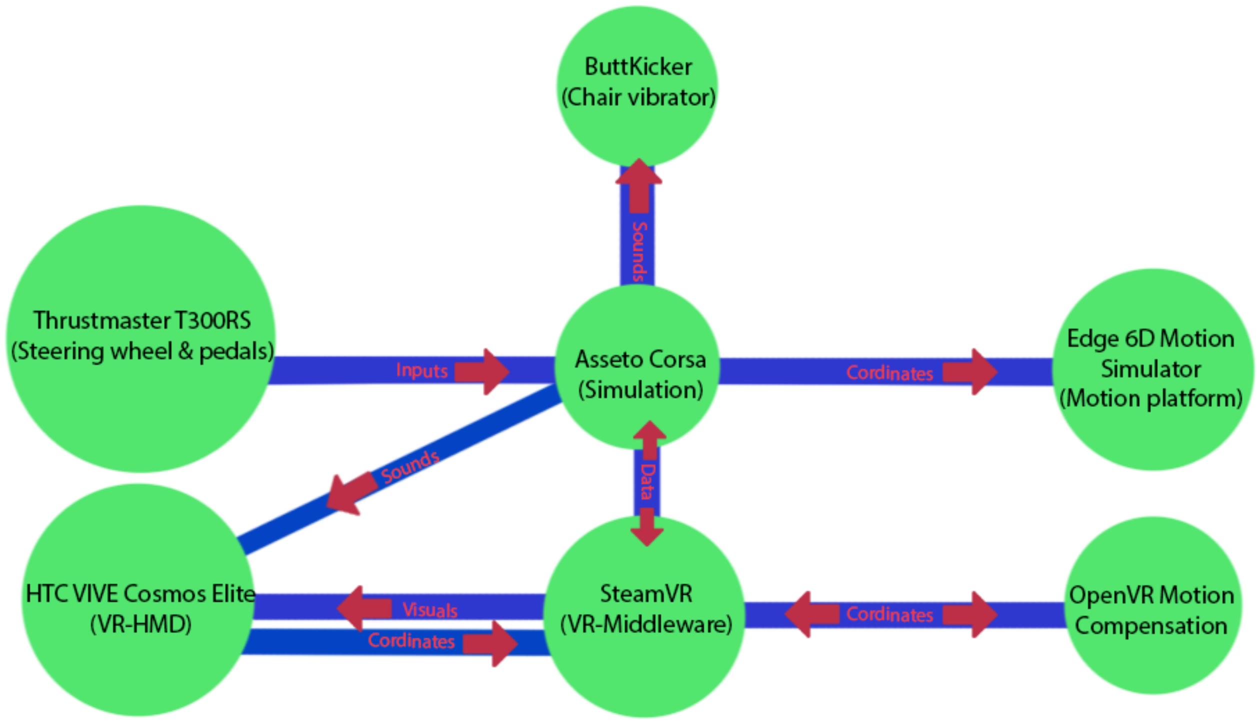


Figure 3.3: Testbed with Motion Platform and VR HMD

.

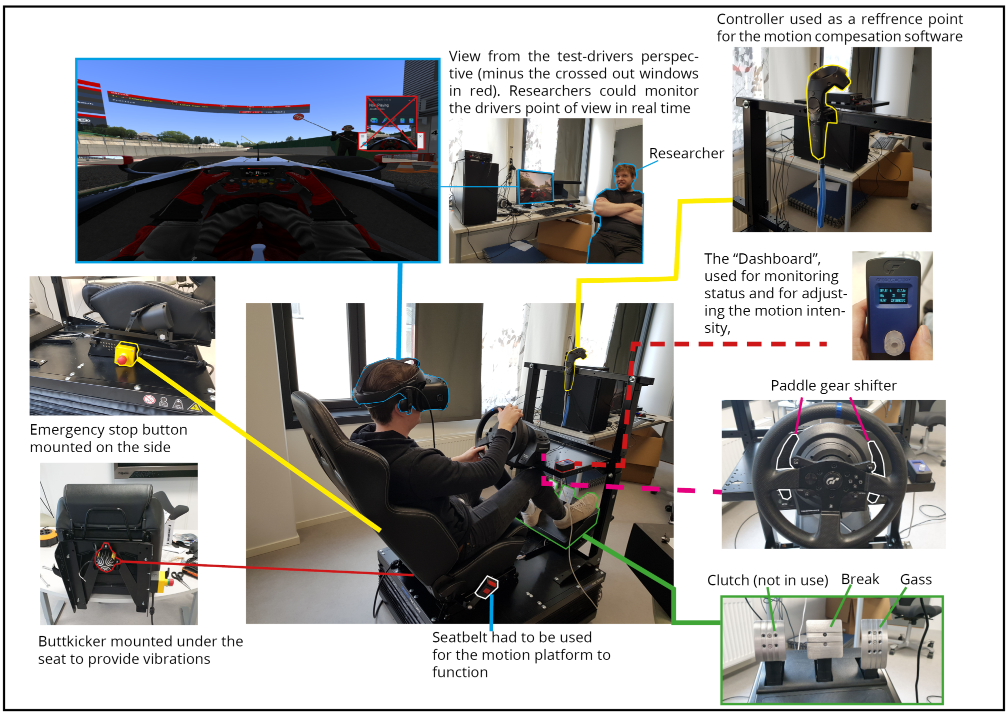


Figure 3.4: A system overview of the experimental setup. For the placement of the lighthouses, see figure 3.5

3.3 Hardware: Steering wheels, Pedals and Simulator-rigs

Forced feedback or haptic feedback is when the hardware returns a physical reaction from the game.[29] In a driving simulator, this can be change of traction on the track through the steering wheel or having the wheel suddenly shake when crashing or bumping. Nat-

Figure 3.5: The motion platform is flanked on both sides with the lighthouses/base stations. It is important that the lighthouses see each other, the headset and the reference controller fastened on the platform.

urally the higher the cost, the better or sophisticated the feedback will be. Additional hardware can also be installed to increase the potential for immersion. Triple-screen monitor setup or using a VR headset will give the user the ability to turn their head and still be in the virtual world. Using a simulator-rig will give forced feedback to the whole body. The quality of the forced feedback and other parameters is of course dependent on the available budget.

3.3.1 Edge 6D Motion Simulator

The purpose of the Edge 6D is to add motion to the participant while in the driving simulation. The Edge 6D was a system capable of delivering the six degrees of freedom(DOF) that we desired, considering our limited time frame and budget. Though there were cheaper systems that delivered 6 degrees of freedom, their quality and performance were questionable.

Edge 6D Motion Simulator[26] is a six DOF motion platform. This motion platform is trying to simulate the motion that is happening with the driver in the simulation. Edge 6D can mount most commercial game controls, monitors, and VR headsets, allowing flexibility with the other tools that were used in the simulation. The motion intensity can also be configured using the systems dashboard as seen in figure 3.4 if you follow the dotted red line from the main picture which can be turned from 0-100. The DOF in motion simulation is based on how many different angles the motion platform can rotate and translate in, see the image 3.6.
The motion platform ordered has removed all unnecessary elements for this simulation. This is both for removing unnecessary clutter on the platform and getting it under budget, as in image 3.7, you see the motion platform without its seat. The Edge 6D Motion works with a high selection of games with very few configurations, and it also worked right out of the box with Assetto Corsa with no configurations. Gforcefactory support team was fast to respond and was informative and helpful for the process of the project.

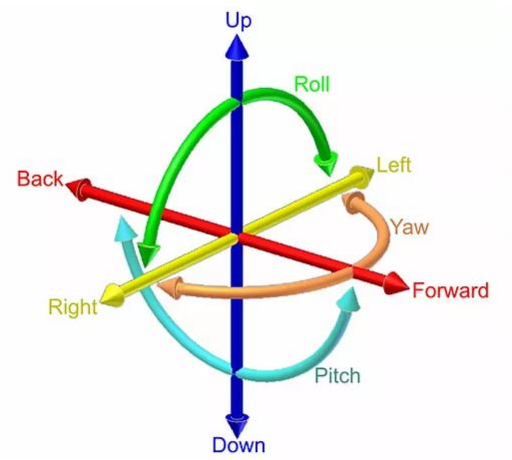


Figure 3.6: A visual representation of 6 different degrees the platform can move in [27]

.

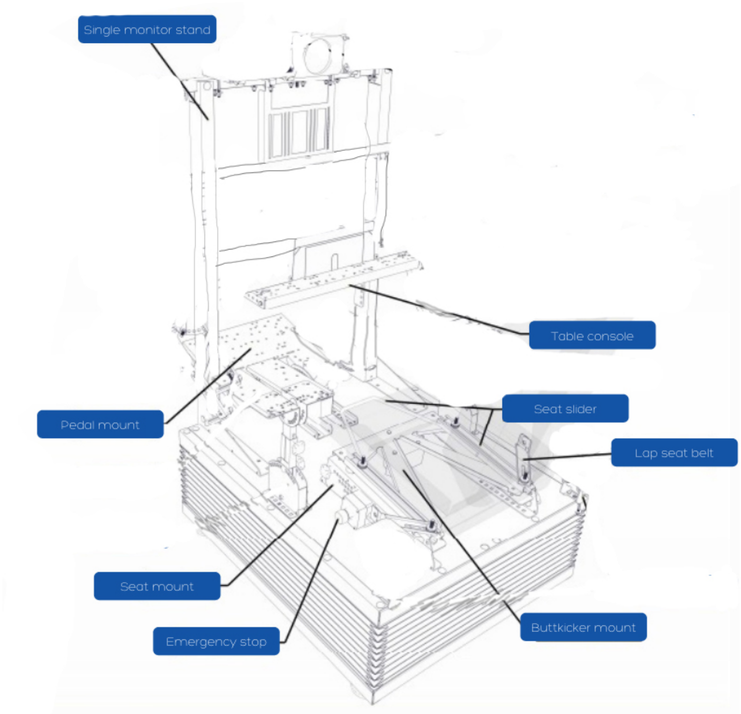
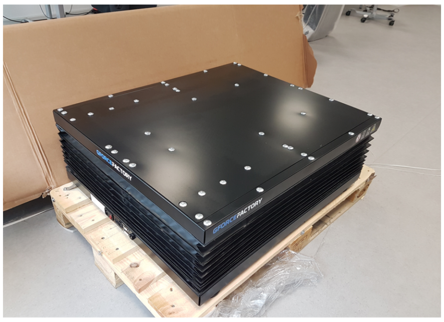


Figure 3.7: The Gforcefactory Edge 6D Motion simulator which provides 6 degrees of freedom, and is an edited copy from Gforcefactory system overview with components that was ordered [26]

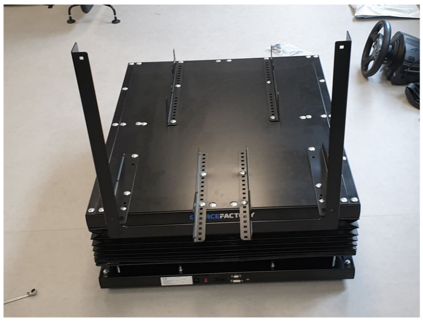
.

The platform was delivered 17.03.2021 and finished assembling and connected with the rest of the setup up the 20.03.2021 as seen in figure 3.8 in the bottom right corner. An invite was sent out to drivers in Align Racing on short notice, where they manage to assemble three drivers to participate in a pilot testing of the motion platform (See chapter 3.8.4).

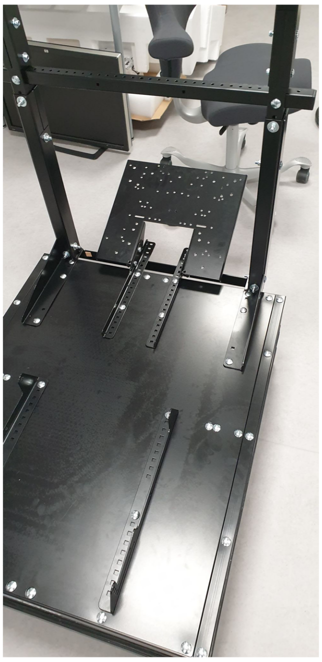
When it came to security, the platform is compact and managed to hide away all movable parts, making the chances of crush-injury minimal. The simulation would stop and return to default position as soon as the seat belt was open. It would also stop when no simulation was running. No one was injured during testing, even when the participants broke protocols.



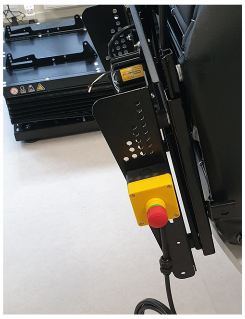
The motion platform and its accessories were delivered in a large cardboard box.



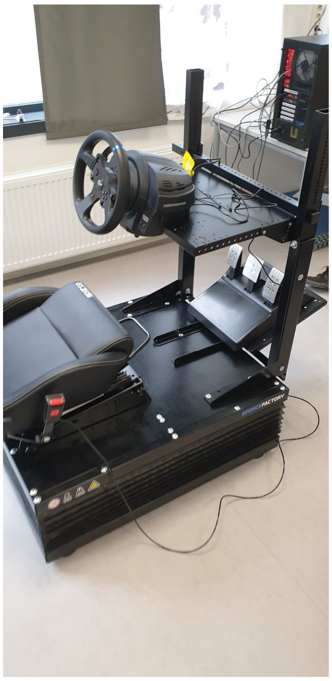
After sorting through all the part, the assembly started by installing the base-layer. This included attachments for the seat-mount, table-mount and pedal-mount.



Installation of the pedal-mount and table-mount. A monitor-mount would also be installed at this point.



Emergency stop button on the side of the seat



The finished installation with a racing seat, wheel and pedals.

Buttkicker installed under the seat.

Figure 3.8: An overview of the platform installation.

.

Architecture	6DOF stewart platform
Control frequency	200 Hz
Control interface	UDP 100 Mbit bi-directional
Dimensions (platform)	0.78 x 0.94 x 0.34 m (incl. floor stands)
Unit weight (platform)	100 kg
Max. payload (incl. user)	150 kg
Linear performance (ISO)	Tx: +- 0.13 m, +- 0.5 m/s, 6 m/s2 (0.6 G)
	Ty: +- 0.10 m, +- 0.5 m/s, 6 m/s2 (0.6 G)
	Tz: +- 0.07 m, +- 0.3 m/s, 5 m/s2 (0.5 G)
Radial performance (ISO)	Rx: +- 15 deg, +- 35 deg/s, 600 deg/s2
	Ry: +- 15 deg, +- 35 deg/s, 600 deg/s2
	Rz: +- 15 deg, +- 40 deg/s, 600 deg/s2
Power requirements	230 V - 3.5 A / 115 V - 7 A (800 W)
Power consumption (average)	200 W
Noise	< 65 dB(A)

Figure 3.9: The technical specifications of the Edge 6D motion platform

.

By consulting with the supplier of the motion platform about what the different levels in the scenario would entail. Conclusions was made that our measurement is based on the pre-scaler value as a quadratic percentage of the actual requested g-force by the simulation. For example, if the pre-scaler is set to a given sum, based on the scenarios and 10 m/s^2 is requested, the platform will try to reproduce:

$$^{*}Scenario\ 0 = \ 0 = 0.00 * 0.00 * 10 = 0.000\ m/s^2$$
$$^{*}Scenario\ 1 = 35 = 0.35 * 0.35 * 10 = 1.225\ m/s^2$$
$$^{*}Scenario\ 2 = 75 = 0.75 * 0.75 * 10 = 5.625\ m/s^2$$

* if no filter or other factors are interfering.

This targeted acceleration in X-direction is fed to both a high pass filter for lateral movement of the platform and a low pass filter for tilting the platform. The platform will also try and correct the lateral movements depending on the amount of still available space for the system to move in before it reaches its maximum length in a certain position. Typically, lateral movements will be very short if the platform is already tilted.

What this means for the different scenarios, is that scenario 2 will produce much more intense and exaggerated movements compared to scenario 1.

3.3.2 ButtKicker

ButtKicker is a vibrating device placed under the driver seat on the motion platform to vibrate the chair based on what the participant is driving on. The purpose of ButtKicker is to give vibrations to the driver's seat to simulate movement that is happening in the game. Typically the driver would feel vibrations from the engine and feelings of the ground when driving on different terrain.
The ButtKicker was more potent if the participant drove on terrain rougher than asphalt, like gravel, grass, or edges of the road.
The ButtKicker [49] operated by taking signals from the PC via the speaker output. The signal then went to a power amplifier which sent the new signal to the ButtKicker which then produced the vibrations.

Settings

Low filter cutoff:	Off
high cutoff frequency:	around 100
high:	Off
intensity:	+1

3.3.3 Thrustmaster T300 RS GT Edition

Thrustmaster T300 RS GT Edition gives the participant the ability to control the vehicle in the simulation.
The Thrustmaster T300 RS GT Edition has two steering-wheel-mounted paddle shifters, where you can easily detach the steering wheel to replace with your custom-made steering wheel. It has a double belt system that creates more realistic forced feedback.

When choosing a steering wheel, there are a couple of attributes to consider. Firstly, as mentioned before, the quality of the forced feedback. Arguably the highest rated model is the Podium Wheel Base DD1, costing 1200 US Dollars. The DD stands for direct drive, which means that the wheel is directly connected to the engine. This gives a more realistic and smooth feeling [14]. Other attributes to consider is the degree of wheel rotation, preferably you want at least 900 degrees of rotation.

The more sophisticated pedals measures force instead of length when pressing down the pedal. Measuring length works fine with clutch and gas pedals. However, brakes in a real car measures not how far you have pressed down, but the pressure of the press. Some pedals can also shake, which simulates breaking with ABS.[14]

This steering wheel was picked was because of the way it switches the gears in the Align Racing car, where they use a paddle behind the steering wheel instead of the gear stick that is usually in regular cars.

3.3.4 HTC Vive Cosmos Elite

HTC Vive Cosmos Elite is a VR-HMD that projects visuals from the simulation to the participant. The headset falls under the category of inside-out as mention in chapter 2.2.1, and uses base-station that emitted infrared lights that are picked up by the VR-HMD and its controllers.

This VR-HMD can give a seamless complete 360-degree view in all directions, immerses the user entirely. With this, the participant can view the virtual world the same manner as in the real world. For instance, the participant can turn his head when reversing, not just trusting his mirrors.

The HTC Vive Cosmos Elite is part of the HTC Vive release set which was released in 02.20.20[67]. The HTC Vive brand is a virtual reality headset developed by HTC and Valve. The headset uses "room-scale" tracking technology, allowing the participant to move in 3D space. HTC Vive Cosmos Elite has a resolution of 1440 x 1700 pixels per eye (2880 x 1700 pixels combined) and a refresh rate of 90 Hz.
As of the time, HTC Vive Cosmos Elite was the newest version of HMD we had available. After the pilot run (See chapter 3.8.4), there was a need for motion compensation or cancellation, and we found an application (See chapter 3.4.3) that was compatible with the HTC Vive Cosmos Elite.

Settings

These setting found in SteamVR are as follows:

Video	
Refresh rate:	90 Hz
Night mode:	Off
Motion smoothing:	Not Supported
Render Resolution:	Auto
Advanced Supersample Filtering:	On

Audio	
Audio output device:	Headset
Audio mirroring:	On
Gain reduction on VIVE HDMI Audio:	On

3.3.5 Computer

Comparably high-end Windows 10 computer. But we feedback from the participant complain about slow response from the computer (lag), it holds a frame rate of 60 frames per second, but we notice we could do a few graphical settings and get the frame rate to 90 frames per second. The computer may not reach the system requirements for our system.

Stats

Processor:	Intel(R) Core(TM) i7-6700K CPU @ 4.00GHz
Installed RAM:	32.0 GB
System type:	64-bit operating system, x64-based processor
Operating system:	Windows 10 Enterprise

3.4 Software: Simulation, Development tools and Plugins/Addons

3.4.1 Assetto Corsa

The simulation was at first planned to be developed in Unity Engine[68] or Unreal Engine[24]. But since Assetto Corsa had opportunity to modifying the game, it was more efficient, in addition to an already established realistic car psychics.
Assetto Corsa is a car racing simulation with developer support, making it possible to implement a custom-made car, which was the initial plan. It also has a high focus on a realistic driving experience. Assetto Corsa uses an advanced DirectX 11 graphics engine that recreates an immersive environment, dynamic lighting, and realistic materials and surfaces. Assetto Corsa has been developed at the KUNOS Simulazioni R&D office. This racing simulator is regarded as highly realistic [43][44]. Assetto Corsa has support for most steering wheels. Assetto Corsa is also compatible and ready for Oculus and OpenVR/VIVE. And was usable without any configuration with our motion platform (See chapter 3.3.1) [59].

Settings

Display	
Resolution:	1920x1080
Rendering mode:	OpenVR early support
Vertical sync:	On
Framerate limit:	Off
Anisotropic filtering:	16x
Anti-aliasing sampling:	4x
World detail:	Maximum
Shadow Resolution:	High
Effect	
Post-processing effect:	On Natural preset
Smoke generation:	Off
View	
Field of view:	120°
Glancing left/right speed:	Middle of the slider
Camera shake at high speed:	1.4
Display downshift protection notification:	On
G-Force effects	
Lateral:	1.4
Vertical:	1.4
Longitudinal:	1.4
Reflection	
Mirror resolution:	High
High quality reflection:	On
Reflection Quality:	High
Reflection rendering frequency:	Low
Audio	
Master volume:	1
Tyres:	0.5
Tyre skid volume onset:	100%
Engine:	1
Surfaces:	0.9
Wind:	0.4

3.4.2 Autodesk 3DS Max

Autodesk 3DS Max was used for modeling and texturing of the Align racing car. it was also where the hierarchy of the car's parts was configured (See chapter 3.1)

Autodesk 3ds Max is a comprehensive 3D modeling and animation tool. Autodesk 3ds Max allows you to be very precise when mapping your creations. The render UVW template function allowing fast template rendering of your prepared UVs, either in wireframe, filled, mapped, or shaded versions. Autodesk 3ds Max is also a powerful 3D animation suite aimed at professional users, with a lot useful of tools and features[32].

In the early stage of development, our information on how to do modification for Align Racing car (See chapter 3.1) in Assetto Corsa[59] where used in 3ds Max. So it became a part of development pipeline for the Car. Also, our development team has some prior experience using 3ds Max.

3.4.3 OpenVR Motion Compensation

The motion compensation was implemented to cancel out the motion of the motion platform. This need arose after the pilot testing in chapter 3.8.4, where we noticed a need to stop the HMD from moving simultaneously with the motion platform. As shown in Figure 3.16 using the Oculus rift as a HMD, the sensor was attached on the platform for motion compensation. This cancelled out the movement of the platform, which made the participant only feel the sensation of movement instead of seeing it as well. However, the tracking was poor and lost connection to the headset often.

This made us make the use of the OpenVR Motion Compensation addon to SteamVR. The Motion Compensation allowed motion simulator to be the reference point for the world, canceling out simulated movement. Head movement was not effected. Ultimately making the participant only feel the motion and not see it, even though he is moving around by the motion platform.
Motion Compensation connects into SteamVR and allows modification of any pose updates from the HMD before it reaches the middleware [21].
One of the controllers are fastened to the platform, making it the reference point for the Motion Compensation program. Motion from the platform is then canceled out, similar to the experiment with the Oculus sensor in the pilot testing (See chapter 3.8.4).

Settings

LPF Beta values:	0.9
Dema Samples:	100
Set Velocity and Acceleration to zero:	On

3.5 Test Participants

Participants for this study were recruited from three groups;

- Group one - acquaintances.
- Group two - volunteers from recruitment emails.
- Group three - Drivers from Align Racing.

Most of the participants recruited where students or employees at the University of Agder. Recruitment began by asking acquaintances and making posts on social media. Many of the participants invited their friends to join the experiment. A recruitment email was also sent to members of the faculty, in the hopes of recruiting older participants. The only requirements for the participants was to be in general good health, and to be physically able to operate the simulator. Altogether, 54 participants partook in the experiment; 40 men and 14 females (age M = 26.60, SD = 8.50). The majority (49 out of 54) of the participants were 20 to 30 years old. 39 out of 54 participants completed all three scenarios, which still left us with a sizeable chunk of data. Some choose not to continue due to motion sickness, while others lost interest. The testing lasted over a period of 4 weeks. Towards the end, people who reported no motion sickness on scenario 0 where not recruited for further experiments, due to time constraints.
The pre-interview found that 87% (47 out of 54) of participants had the drivers licence. 30 participants had at least some experience with VR while 8 had a lot and 15 reported none. Similarly regarding experience with racing games, 30 participants reported "some" while both "A lot" and "none" had 12 each. When participants were asked to report their likelihood of MS from other sources (See figure 3.10), most reported that they "never" or "sometimes" obtained the sicknesses

presented. The Align racing drivers had generally more experience with sim-racing and real racing, which would be less expected amongst the two groups. Most of the participants were students or employees of University of Agder. Aside from the drivers from Align racing, none had notable experience with sim-racing or racing in general. In the end, two participants participated in the study, where none finished all the scenarios. Participants partook in scenario 0 first, followed by scenario 1 and lastly scenario 2. 8 participants conducted scenario 2 before scenario 1 to test for VR adaption. However, only finished all three scenarios.

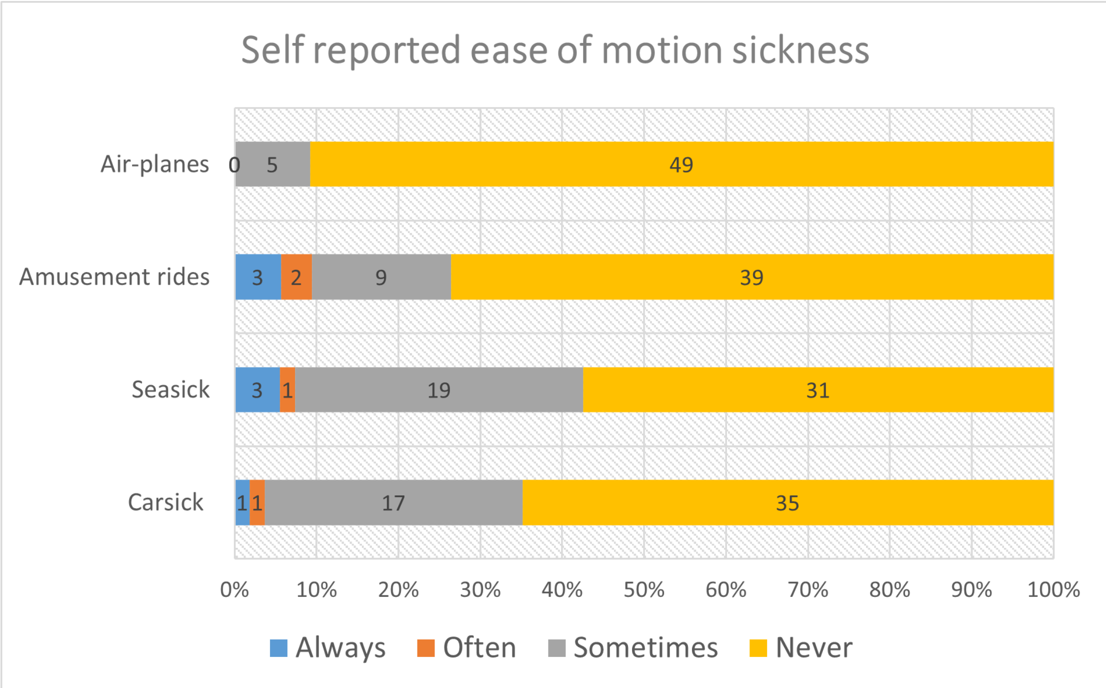


Figure 3.10: The majority of participants reported generally low chances of being sick trough all four activities.

.

3.6 Stimuli and Apparatus

We used the EDGE 6D motion platform 3.7, capable of 6 degrees of freedom (6DOF), manufactured by Gforcefactory (see figure 3.9 for technical specifications). The motion platform provided the participant with vestibular motion that mimicked motion from the racing-application. A dashboard connected to the motion platform enabled us to set the motion intensity. Participants were seated on a R100 SKY sport seat and secured with a switched lap seat-belt. Additionally, the simulator had a "Buttkicker" installed, which provided the user with vibrations through the seat (See chapter 3.3.2). Participants used a HTC Vive Cosmos to view the racing-application in virtual reality. Third party software was also used for motion cancellation (See chapter 3.4.3). The application used was Asseto Corsa (See chapter 3.4.1). This game was compatible with the motion platform without any configuration. For steering, the participants used a wheel and pedals from the Thrustmaster T300RS package (see chapter 3.3).

3.7 Experimental Research Design

The experiment used a within-subjects design, where each participant tested each condition. One reason was to ensure that the experiment would have enough participants for each scenario. For example, rather than dividing up a sample of 30 participants into the three conditions, the within subjects design allow for 30 samples of all conditions instead of 10. As mentioned above, the platform supported configuring of the motion-intensity, which acted as our independent variable. Ultimately, we wanted to look for symptoms of simulation sickness as the dependent variable. Cybersickness was measured using the SSQ along with questions in the post-interview where participants could elaborate on their answers. Some other variables kept in mind were the participants self-assessment on their own tolerance for motion sickness caused by car, plane, boat or roller-coasters. We also looked at age and gender. Previous experience with VR and/or VR-racing was also interesting, and also experience with real life racing. Real life racing ranged from go-carting to Professional racing sports.
The participant will be directed to drive to their best ability and have no time pressure or goal that needs to be achieved during driving.
For assessment, we use a Simulator Sickness Questionnaire (SSQ) [36] before and after each session in the simulation. During the simulation, the fast motion sickness questionnaire[37] was applied (See chapter 2.4). Each minute under stimuli, test participants reported back a number from 0 - 20 where 0 was "I don't feel anything," and 20 is "I can't take it anymore." There were also notes taken under simulation about driving performances, anything unusual, and noting who drives fast and crashed a lot.

3.7.1 User Testing Scenarios

Table 3.1 describes the scenarios which participants tested. Scenario 0 had the motion turned off while 1 and 2 had the motion platform turned on. Each scenario was divided into different sessions of the day or done on another day. Each scenario has the same track. The test conductor did not inform the participant on what motion intensity the platform was set to.

Scenario	Motion Intensity	Buttkicker	Information
0	0%	No	This provided us with baseline data that was compared with results from the other tests. The scenario also acted as an introduction where participants got familiar with the apparatus.
1	35%	Yes	Chosen is a standard motion, and participants received a clear sense of activity from the platform
2	75%	Yes	This scenario provides the participant with intense motion. It may act as an indication if more movement will lessen or generate more symptoms.

Table 3.1: User test scenarios

.

3.7.2 User Testing Procedure

Each participant was allocated scenario 0 first and then scenario 1 and scenario 2.
All the scenarios proceeded identically aside from scenario 0 where a pre-interview was conducted along with a consent form. After the participant signed the consent from, the pre-interview was conducted. Their answers were recorded in a Word-document. In scenario 1 and 2, participants were greeted and their general well being was evaluated with the SSQ before proceeding to the simulation. All SSQ answers were recorded with Microsoft forms. Participants were then briefed on the FMS. Before driving, the participant were asked to do their best, and a timer was set for ten minutes. The participant was however free to stop at any time. The time was noted down if the participant stopped before the time had ran out. When seated in the motion platform, the participant would adjust the seat to their liking. The motion platform would then be configured to the demands of the scenario. The map and car was then selected and the driving commenced. Any comments from the participants while driving would be recorded and noted down. After the participant had finished a scenario, the post-questionnaire was conducted along with the second SSQ. Both the post-interview and SSQ were conducted after each scenario. The motion platform, seat, VR-HMD, steering wheel and pedals was disinfected between each use. Participants were also asked to disinfect their hands before and after use. This was done because of the Covid-19 pandemic Due to the nature of simulation sickness, participants were discouraged to carry out more than one scenario in the same day. However, participants had the option to partake in more scenarios the same day granted they had a minimum 3 hour of respite and showed no symptoms.

3.8 Data Collection and Evaluation Methods

The simulation sickness questionnaire (SSQ) was used for assessment of cybersickness. A pretest-interview and a post-interview was conducted to gather additional information. The pretest-interview gathered general information, such as age, gender and previous experiences (see appendix A.1). Additionally, a post-test-interview was used to collect the participants experience. Moreover, the post-test-interview also contained questions designed to pinpoint moments during the test which caused simulation sickness (See appendix A.3).
A note kept in mind was to avoid overwhelming participants with questionnaires, due to the risk of survey fatigue, which Walch et al. [69, p. 2986] noted in their study of cybersickness. However to get the data needed, some questionnaires had to be answered. There are many viable and proven questionnaires to measure MS and CS, as presented in the State of the art chapter.

3.8.1 Self reporting questionnaires

The main form of data collection went through self reporting questionnaires.

Simulation sickness questionnaire

Each item in the Simulator Sickness Questionnaire (SSQ) is a scale from "none", "slight", "moderate" to "severe". Based on these you score them from none = 0, slight = 1 , moderate = 2, severe = 3. Then multiply the values based on these scales "Nausea" x 9.54, "Oculomotor" x 7.58 "Disorientation" x 13.92, with each all to their subscore. A Total Score is also the score representing the overall severity of simulation sickness which takes all the values and multiply it with 3.74. [70] To find which symptoms apply to which score, see figure 3.11

SSQ has three clusters of symptoms (See chapter 2.3.3):

SQQ symptoms that accounts for nausea are general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and burping.
While oculomotor symptoms are calculated using general discomfort, fatigue, headache, eye strain, difficulty focusing, difficulty concentrating, and blurred vision.
And finally, the calculations for disorientation are difficulty focusing, nausea, fullness of head, blurred vision, dizziness, and vertigo.

The minimum score of an SSQ is 0 on all the posts, and its maximum is 200.34 for Nausea, 159.18 for Oculomotor, 292.32 for Disorientation, and 235.62 for Total score.

Symptoms	Weights for Symptoms		
	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eye strain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total*	[1]	[2]	[3]

Figure 3.11: SSQ symptoms scale [70]

The calculation that were used to calculate the different scores are:

$$Nausea = \begin{pmatrix} general\ discomfort + increased\ salivation + sweating + nausea + \\ difficulty\ concentrating + stomach\ awareness + burping \end{pmatrix} \times 9.54$$

$$Oculomotor = \begin{pmatrix} general\ discomfort + fatigue + headache + eyestrain + \\ difficulty\ focusing + difficulty\ concentrating + blurred\ vision \end{pmatrix} \times 7.58$$

$$Disorientation = \begin{pmatrix} difficulty\ focusing + nausea + fullness\ of\ head + \\ blurred\ vision + dizziness + vertigo \end{pmatrix} \times 13.92$$

$$TotalScore = \left(\begin{pmatrix} general\ discomfort + \\ increased\ salivation + \\ sweating + nausea + \\ difficulty\ concentrating + \\ stomach\ awareness + burping \end{pmatrix} + \begin{pmatrix} general\ discomfort + \\ fatigue + headache + \\ eyestrain + difficulty \\ focusing + difficulty \\ concentrating + blurred\ vision \end{pmatrix} + \begin{pmatrix} difficulty\ focusing + nausea + \\ fullnessofhead + blurred \\ vision + dizziness + vertigo \end{pmatrix} \right) \times 3.74$$

Where about each of these values can be from zero to three based on the given answer. Examples of this are the participant feels a severe level of nausea, slight fatigue, and moderate general discomfort while not having any other symptoms. Then the calculation is going to be:

$$Nausea = (2 + 0 + 0 + 3 + 0 + 0 + 0) \times 9.54 = 47.7$$

$$Oculomotor = (2 + 1 + 0 + 0 + 0 + 0 + 0) \times 7.58 = 22.74$$

$$Disorientation = (0 + 3 + 0 + 0 + 0 + 0) \times 13.92 = 41.76$$

$$TotalScore = ((2+0+0+3+0+0+0) + (2+1+0+0+0+0+0) + (0+3+0+0+0+0)) \times 3.74 = 41.14$$

What is considered a high score is disagreed upon and there is not a consensus among the earlier papers of what is defined as a high score. But according to the aviator dataset to Kennedy, where all average subscale scores that were above 20 was considered a "bad simulator"[36]. (See figure 3.12)

Table 1. Categorization of symptoms based on central tendency (i.e., mean or median) values for each simulator.

SSQ SCORE	CATEGORIZATION
0	No symptoms
<5	Negligible symptoms
5-10	Minimal symptoms
10-15	Significant symptoms
15-20	Symptoms are a concern
>20	A bad simulator

Figure 3.12: Picture taken from Stanney paper Cybersickness is not simulator sickness [61] Kennedy mean list of mesuring the simalation

A study with college students in flight-unrelated virtual environments revealed considerably higher scores on the SSQ compared to Kennedy's aviator dataset. Their results from eight different studies and institutions resulted in an overall average SSQ total score of 29. (See figure 3.13 [61].

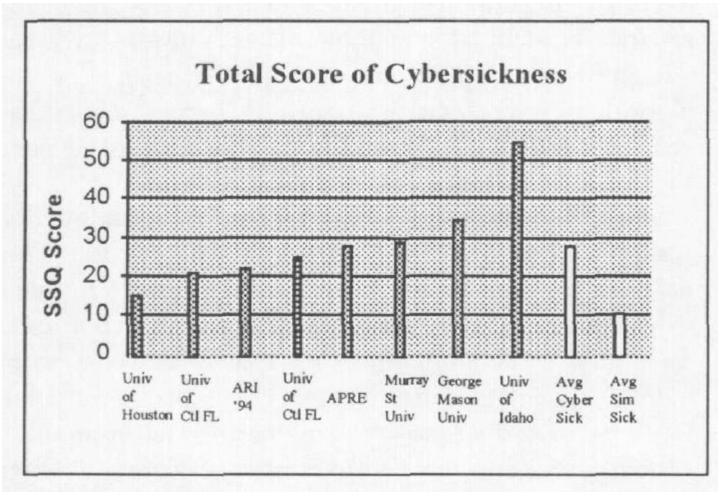


Figure 3.13: Cybersickness is not simulator sickness [61] on page 1140 that show the average from 8 studies

Rasch analysis

Using Ministep and Rasch analysis [11], a PEARSON score table is generated (see table 3.14). This table presents the theoretical highest and lowest score possible for a participant. The two main points of interest are "Score" and "Measure". S.E is the Standard error. The total score is calculated from the scale used in the questionnaire, from "Strongly disagree" (1) to "Strongly agree" (6). In table 3.14, the Measure field has been transposed to 0-100. This means that if a participant would answer "Strongly disagree" on all questions, that would result in a score of 19 and a measure of 0. On the other hand, answering "Strongly agree" on all questions would result in a score of 114 and a measure 100. Ultimately, the table provides context to help interpret which scores and measures should be regarded as high or low. The rasch analysis has been used in context of the Game engagement questionnaires calculations.

Game engagement questionnaire

The Game engagement questionnaire (GEQ) was added after 10 participants had completed scenario 0. This lead to lower responses on scenario 0 than the other scenarios. The addition came after a need for testing the engagement and enjoyment of the experience. This would provide data which could be compared between all three scenarios. Some of the reasons for choosing VR as display is the increase of presence and engagement it provides. It would therefore be interesting to see what impact the motion platform in addition to VR has on game enjoyment and engagement, if any. One change that diverts from the original GEQ is question 7 - "I get wound up". To get "wound up" is defined by the Cambridge Dictionary as someone who are being *very worried, nervous, or angry* [15]. Nonetheless, for this study, a decision was made to interpret the question as "excitement". This change made the question more positive. Moreover, the modified question would still be in the measurement category of "flow". As mentioned in section 2.4.1, enjoyment is a part of flow. Excitement can be seen as being closely related to enjoyment, and thus still be in the category of flow. A change was also made regarding question 17 "I play longer than I mean to". Since the scenarios were set to 10 minutes with driving, this question was verbally rephrased to "Had you played longer if we had not stopped you?". Interestingly, other experiments have kept the original question, despite having a fixed playing time as well [13]. In their testing, Brockmyer et al. [13] administered the GEQ both before and after the testing. For this experiment, participants would answer the GEQ only after each scenario.

Fast motion sickness scale

To monitor a participant‘s evolving MS, the fast motion sickness scale (FMS) was adopted. Before testing each scenario, the participant was briefed on the FMS. A researcher would tell the participant that he would prompt them verbally each minute. The participant would then report back on their MS symptoms translated into a number from 0-20 (0 = fine while 20 = On the verge of regurgitating). Answers were recorded in a spreadsheet.
The final excel sheet had data for each minute. By finding the average for each minute, a graph (See figure 4.7) was created to find the mean development of MS for the scenarios. All the peak scores for each test were found and organized into the scenarios.

Self reported probability of motion sickness

In the pre-scenario 0 questionnaire, participants were asked to rate their probability towards different types of MS inducing activities. There were four type of activities: Carsick, seasick, amusement-ride sick and airplane-sick. The rating scale used was: Always, often, sometimes and never. To process this data, the scale would be assign points where "always" = 4, "often" = 3, "sometimes" = 2 and "never" = 1. The score is then summarized and labeled "Probability of MS score"(POMS). Naturally, higher scores means that the participant thinks they are more prone to MS. The maximum score achievable is then 16 (4×4), and a minimum score of 4 (4×1). This calculation is meant to be used as an indication, since it does not take into account the weight of each option.

3.8.2 Correlation calculation

All calculations regarding correlation was produced using the data analyis function "t- Test: Paired Two Sample for Means" in Microsoft Excel. An independent t-test produces a probability score "ρ" and a Pearson correlation score "r". The ρ value ranges from 0 to 1 and regards

TABLE OF MEASURES ON TEST OF 19 ITEM

SCORE	MEASURE	S.E.	SCORE	MEASURE	S.E.	SCORE	MEASURE	S.E.
19	.00E	14.67	51	43.70	1.66	83	54.45	1.81
20	9.92	8.20	52	44.04	1.64	84	54.87	1.83
21	15.91	5.95	53	44.38	1.63	85	55.30	1.86
22	19.59	4.97	54	44.71	1.62	86	55.74	1.89
23	22.33	4.39	55	45.04	1.61	87	56.19	1.92
24	24.53	4.00	56	45.36	1.60	88	56.66	1.95
25	26.38	3.69	57	45.68	1.60	89	57.15	1.99
26	27.98	3.45	58	46.00	1.59	90	57.66	2.03
27	29.38	3.24	59	46.32	1.59	91	58.18	2.07
28	30.62	3.06	60	46.63	1.58	92	58.73	2.11
29	31.74	2.90	61	46.95	1.58	93	59.30	2.15
30	32.74	2.76	62	47.26	1.58	94	59.89	2.20
31	33.65	2.63	63	47.58	1.58	95	60.51	2.25
32	34.48	2.52	64	47.89	1.58	96	61.16	2.30
33	35.24	2.41	65	48.20	1.58	97	61.85	2.36
34	35.94	2.32	66	48.52	1.59	98	62.56	2.42
35	36.60	2.24	67	48.83	1.59	99	63.32	2.49
36	37.21	2.17	68	49.15	1.59	100	64.12	2.57
37	37.79	2.11	69	49.47	1.60	101	64.98	2.65
38	38.33	2.05	70	49.80	1.61	102	65.90	2.75
39	38.84	2.00	71	50.12	1.62	103	66.88	2.86
40	39.33	1.95	72	50.45	1.62	104	67.95	2.98
41	39.80	1.91	73	50.78	1.63	105	69.12	3.12
42	40.25	1.87	74	51.12	1.65	106	70.41	3.29
43	40.68	1.84	75	51.47	1.66	107	71.84	3.48
44	41.09	1.81	76	51.81	1.67	108	73.46	3.71
45	41.50	1.78	77	52.17	1.69	109	75.33	4.01
46	41.89	1.75	78	52.53	1.70	110	77.54	4.41
47	42.27	1.73	79	52.90	1.72	111	80.29	4.99
48	42.64	1.71	80	53.27	1.74	112	84.01	5.97
49	43.00	1.69	81	53.66	1.76	113	90.04	8.22
50	43.35	1.67	82	54.05	1.78	114	100.00E	14.69

Figure 3.14: A PEARSON score table generated with Ministep, using a Rasch Analyses for N = 43 [11]

TABLE OF MEASURES ON TEST OF 19 ITEM

SCORE	MEASURE	S.E.	SCORE	MEASURE	S.E.	SCORE	MEASURE	S.E.
19	.00E	16.59	51	42.72	1.71	83	52.80	1.86
20	11.05	9.15	52	43.05	1.70	84	53.18	1.88
21	17.49	6.50	53	43.36	1.69	85	53.58	1.91
22	21.28	5.31	54	43.67	1.68	86	53.99	1.94
23	23.96	4.58	55	43.98	1.67	87	54.42	1.97
24	26.02	4.08	56	44.29	1.66	88	54.85	2.01
25	27.68	3.70	57	44.59	1.65	89	55.31	2.04
26	29.07	3.40	58	44.89	1.65	90	55.78	2.08
27	30.25	3.16	59	45.19	1.64	91	56.27	2.13
28	31.29	2.97	60	45.49	1.64	92	56.77	2.17
29	32.21	2.80	61	45.78	1.63	93	57.31	2.22
30	33.03	2.67	62	46.08	1.63	94	57.86	2.27
31	33.78	2.55	63	46.37	1.63	95	58.44	2.32
32	34.47	2.45	64	46.67	1.63	96	59.05	2.38
33	35.11	2.36	65	46.96	1.63	97	59.70	2.44
34	35.71	2.29	66	47.26	1.64	98	60.37	2.51
35	36.27	2.22	67	47.55	1.64	99	61.09	2.59
36	36.80	2.16	68	47.85	1.65	100	61.86	2.67
37	37.30	2.11	69	48.15	1.65	101	62.67	2.76
38	37.78	2.06	70	48.45	1.66	102	63.55	2.87
39	38.24	2.02	71	48.76	1.67	103	64.49	2.99
40	38.68	1.98	72	49.07	1.67	104	65.53	3.13
41	39.10	1.94	73	49.38	1.68	105	66.67	3.29
42	39.51	1.91	74	49.69	1.70	106	67.93	3.48
43	39.91	1.88	75	50.01	1.71	107	69.36	3.71
44	40.29	1.85	76	50.34	1.72	108	71.00	3.99
45	40.66	1.82	77	50.67	1.74	109	72.91	4.35
46	41.03	1.80	78	51.00	1.75	110	75.23	4.82
47	41.38	1.78	79	51.35	1.77	111	78.15	5.51
48	41.73	1.76	80	51.70	1.79	112	82.17	6.65
49	42.07	1.74	81	52.06	1.81	113	88.82	9.25
50	42.40	1.73	82	52.42	1.83	114	100.00E	16.64

Figure 3.15: A PEARSON score table generated with Ministep, using a Rasch Analyses for N = 24 [11]

probability. If the value of ρ is > 0.05, then the calculation will be deemed as no correlation. The Pearson correlation (r) ranges from 0 to 1 (can be both negative and positive) and describes how correlated two parameters are. Higher r values means more correlation. Imagine a scatter-plot such in figure 4.12. "r" closer to 0 would generate more horizontal lines while values closer to 1 would generate steeper lines.

3.8.3 Semi-Structured Interviews

After each scenario, participants were asked questions regarding their experience (See appendix A.1). This would generally spark a little conversation between the interviewer and the participant. After some interviews, the interviewer would get a sense of which causes that typically generated discomfort: Crashing, spinning out, acceleration, breaking, turning were common causes for sickness. When compiling the answers, the interviewer would try to organize them into categories, such as crashing, vection or unusual feeling.

3.8.4 Pilot testing

After the assembly of the motion platform (20.03.2021) (See figure 3.8), a pilot-test was conducted to investigate how the platform worked in order develop further test scenarios. As this was a pre-test to ensure the platform worked as intended for the real tests, no SSQ were issued. Three drivers from Align Racing participated in this pilot test.
They were seated in the motion platform using an Oculus rift S as display. The motion platform and accessories were cleaned using disinfectant disposable washcloths after each participant. Unstructured interview were conducted while participant operated the simulation, questions were concerning technical issues in the simulation. The drivers were issued the imported Align Racing car which was modded inn beforehand. Later in the testing, the car was switched to a default Asseto Corsa car. The maps were Spa, Trento-bondone and Monza.
One of the participants reported that the view in the HMD would dislocate itself from the standard position and relocate to an unrealistic place outside the car whenever the motion platform moved. The motion intensity of the platform was lowered to hinder this. However, the intensity had to be lowered to the point where the platform was barely moving.
Further, the participants commented that the view-port of the HMD moved with the motion platform. In-game, the users view port would move with the platform when turning, breaking and accelerating. This was not optimal as it created unrealistic and uncomfortable visual stimuli and could lead to more simulation sickness. The solution required us to switch to an Oculus Rift with an Oculus-Sensor (See figure 3.16). By placing the sensor on the motion platform in front of the user, the sensor would move with the platform thus eliminating the aforementioned problems. Though this switch made the driving much more enjoyable, the tracker would loose connection to the headset for some periods of time. Moving the sensor closer towards the user improved the tracking, however there were still instances where the tracking would fail. This lead to the discovery of a motion compensation tool designed for VR with lighthouses and controllers. One controller was fastened to the platform which cancelled out the motion (See chapter 3.4.3). This solution enabled the use of HTC Vive Cosmos (See chapter 3.3.4) which supported higher FOV, resolution and framerate.
The participant also claims that there may be an indication that the Align Racing car in the simulation was unrealistically fast, giving it a feeling of flying.

Figure 3.16: Motion compensation setup with Oculus Rift.

Chapter 4

Results and discussion

52 participants partook in a minimum of one scenario, 44 did at least two, and 39 completed all three scenarios. Among the ones that finish all the scenarios, there were 29 men and nine women. The age of the participants were significantly dominated by young people where only five were over the age of 30 and three completed all scenarios. The following SSQ calculations will be from this group of 39. Regarding the GEQ, 45 answered a minimum of two times and 26 answered all three questionnaires.

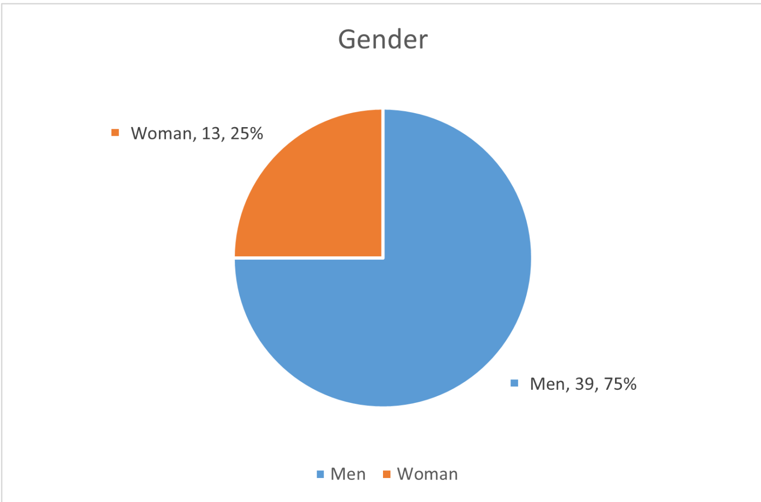


Figure 4.1: Gender demographic of the test participants

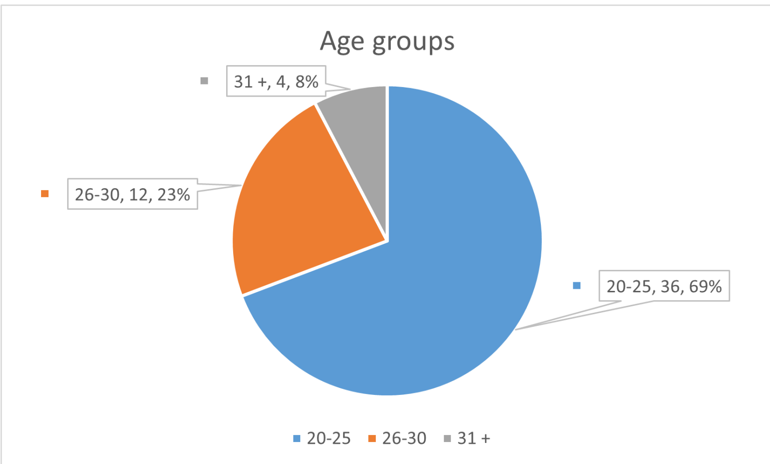


Figure 4.2: Shows the age grouping of the participants. The test has far more under 30 years old than above.

4.1 Simulators effect on motion sickness

After completing SSQ according to our planned procedure (See chapter 3.7.2) where the participants self reported symptoms for SS and calculating the results (See chapter 3.8.1) from the SSQ. The following results only take into account the participant that did all of the scenarios:

The following SSQ results only displays results from the participant that completed all three scenarios. These calculations need all the participant to have finished all the scenarios. Doing these calculation with participant that did not complete all scenarios would result in calculating that may distort the numbers and make it impossible to compare the different scenarios. Examples: One participant with a high SSQ score is taking one or two of the scenarios scoring high, but not joining the rest will give a false average. SD is high due to the most number scored in most of the cases is zero as can been seen by looking at mode in the result appendix B.2 and B.4.
The "Total score" of each of the scenarios as shown by the green pillar in figure 4.3, shows that scenario 1 came out worst with a total score of 34.24 (SD = 32.81) while scenario 2 "Total score" of 23.69 (SD = 23.08). Worst and best scenario where scenarios with motion.

The results from scenario 0 presents a mean "Total score" of 25.59 (SD = 27.25). In this scenario, women scored the highest with a mean score of 28.26 (SD = 27.94) compared to men mean of 23.69 (SD = 27.14). Then preceding to scenario 1, out of all three scenarios, scenario 1 had the highest SSQ "Total score" with a mean of 34.24 (SD = 32.81) where men scored significantly higher than women (Men M = 36.65, SD = 33.17, Women M = 22.86, SD = 30.81). Over all the scenarios, scenario 2 had the lowest SSQ score for women (Men M = 26.06, SD = 23.79, Women M = 20.36, SD = 18.16) (See Datasheet A figure B.1).

According to figure 4.3, "Disorientation" scored the highest in scenario 1 (M = 48.90, SD = 46.85), follow by "Nausea" which also scored its highest in scenario 1 (M = 27.40, SD = 29.08) and "Oculomotor" scored the lowest in scenario 1 (M = 20.99, SD = 25.37). This trend where "Disorientation" scored highest followed by "Nausea" and lowest "Oculomotor", was true for all three scenarios. But as a notice in figure 4.3, "Nausea" is worse in scenario 2 (M = 22.26, SD = 21.85) than in scenario 0 (M = 19.08, SD = 24.63). "Oculomotor" also had an increase in scenario 2 (M = 13.99, SD = 15.69) from scenario 0 (M = 13.02, SD = 20.16). Contradictory to this trend, "disorientation" scored lower in scenario 2 (M = 32.37, SD = 33.27) than in scenario 0 (M = 42.47, SD = 42.87).

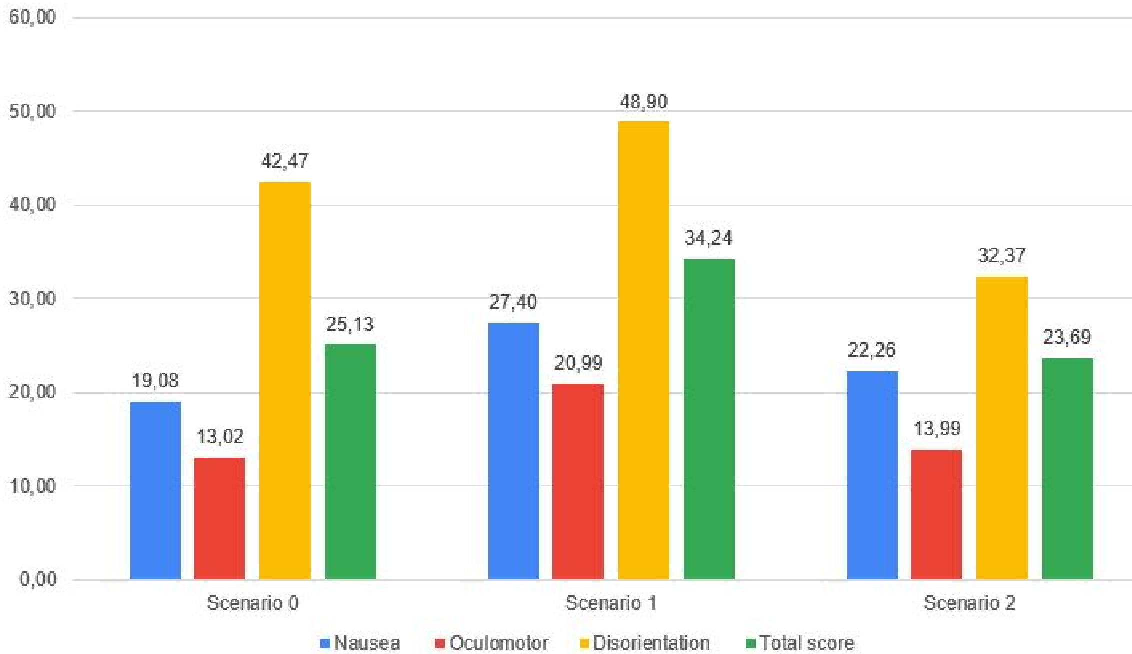


Figure 4.3: Average SSQ score for each scenario, comparing symptoms score in each scenario

Figure 4.4 gives a clear indication of what symptoms affected each scenario. For instance its clearer to observe the rise of "Nausea" and "Oculomotor" score from scenario 0 to scenario 2.

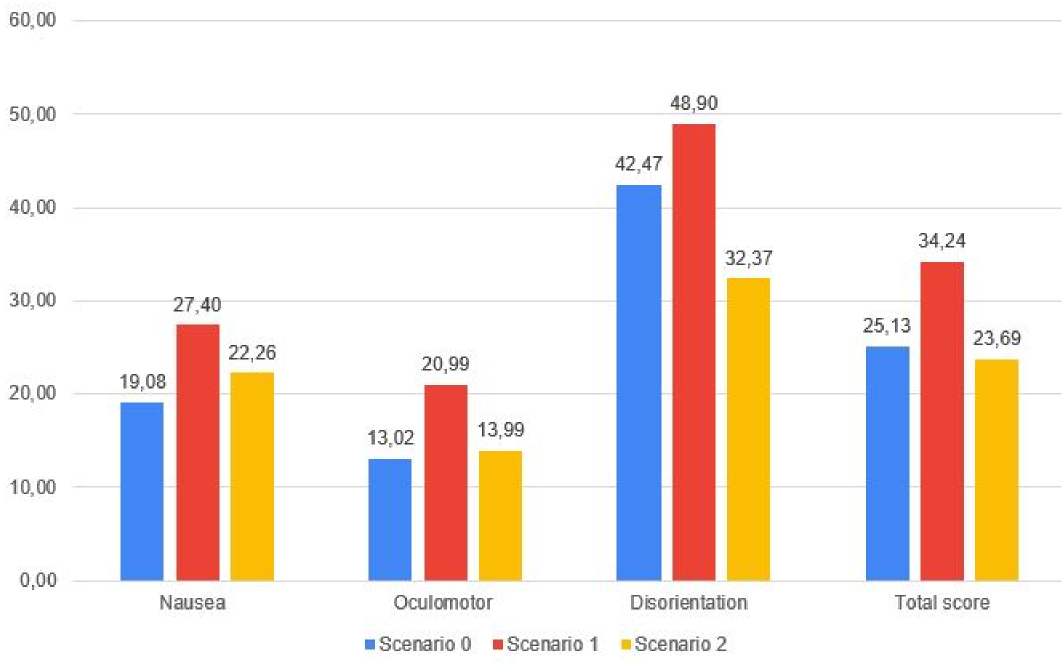


Figure 4.4: Average SSQ score for each scenario, comparing scenario which each symptoms

Earlier in this chapter, it was presented that women overall scored higher than men except in scenario 0.
However, comparing the genders in detail resulted in some exciting findings. If we break down each symptom group for each scenario, they seem to be affected differently. Remember that scenario 0 had no motion, the women did worse here in Total score (M = 28.26, SD = 27.94), but according to figure 4.5 this seems to be due to their higher score in "Disorientation" (M= 52.59, SD = 44.88) compared to men (M = 38.51, SD = 41.97). However, their "Nausea" is almost equal (M = 20.14, SD = 26.01) to men (M = 18,76, SD = 23,95) and with "Oculomotor" it is completely the same (Women M = 12.63, SD = 22.31)(Men M = 12.63, SD = 19.86).
Women's symptom scores drop significantly in scenarios with motion as seen in figure 4.5. This is however not the case with "Oculomotor" where they get the highest score for this symptom in scenario 2 (M = 16.00, SD = 14.49). Further, in scenario 2 women score lower then men in all "Nausea" (M = 16.96, SD = 15.43) and "Disorientation" (M = 28.12, SD = 30.64). Women also had the lowest total score in scenario 2 (M = 20.36, SD = 18.16). In contrast, according to the results, men's symptoms increases with motion except from "Disorientation" which get a score of 35.04 (SD = 33.72). In scenario 1, men scored the highest overall in each category (Nausea M = 27.67, SD = 28.51) (Oculomotor M = 23.75, SD = 26,70) (Disorientation M = 52.43, SD = 46.67) (Total Score M = 36.65, SD = 33.17), indicated by the tallest blue column in each 1 bracket for each symptoms group in figure 4.5. Men got a lower score in every symptom in scenario 2 compared to scenario 1. Men also scored lower in scenario 2 compared to scenario 0 in "Disorientation" with a mean score of 35.04 (SD = 33.72) (See figure 4.5 and listed Datasheet in figure B.1).

9 participants in scenario 0, and 12 participants in scenario 1 that scored over 50 in the SSQ. Interestingly, only 5 people scored above 50 in the last scenario.
Of all the participants that finish all three scenarios, all 15 of them reach a combined total higher than 100 in "Total Score", and 9 of them reach a combined total higher than 150. Both of the prior mentioned groups follow the same pattern where they get their highest score in scenario 1 and lowest score in scenario 2. The ones with combined total score over 150, scored in scenarios 0 a mean of 53.61(SD = 86.02), scenarios 1 scored mean of 81.45 (SD = 127.16) and scenarios 2 score mean = 53.19 (SD = 86.02). This presents that even those who scored highest on the SSQ, followed the same pattern as the overall average. (See Datasheet in figure B.3)

Due to our lack of elderly participants, we can't formulate speculation if age affects simulation sickness. With that said, our elderly (31 years +) there are only 2 the completed all of scenarios where about both scored a mean of 11,22 (SD = 3,74) in scenario 0, 35,53 (SD = 1,87) in scenario 1 and 13,09 (SD = 5,61) in scenario 2

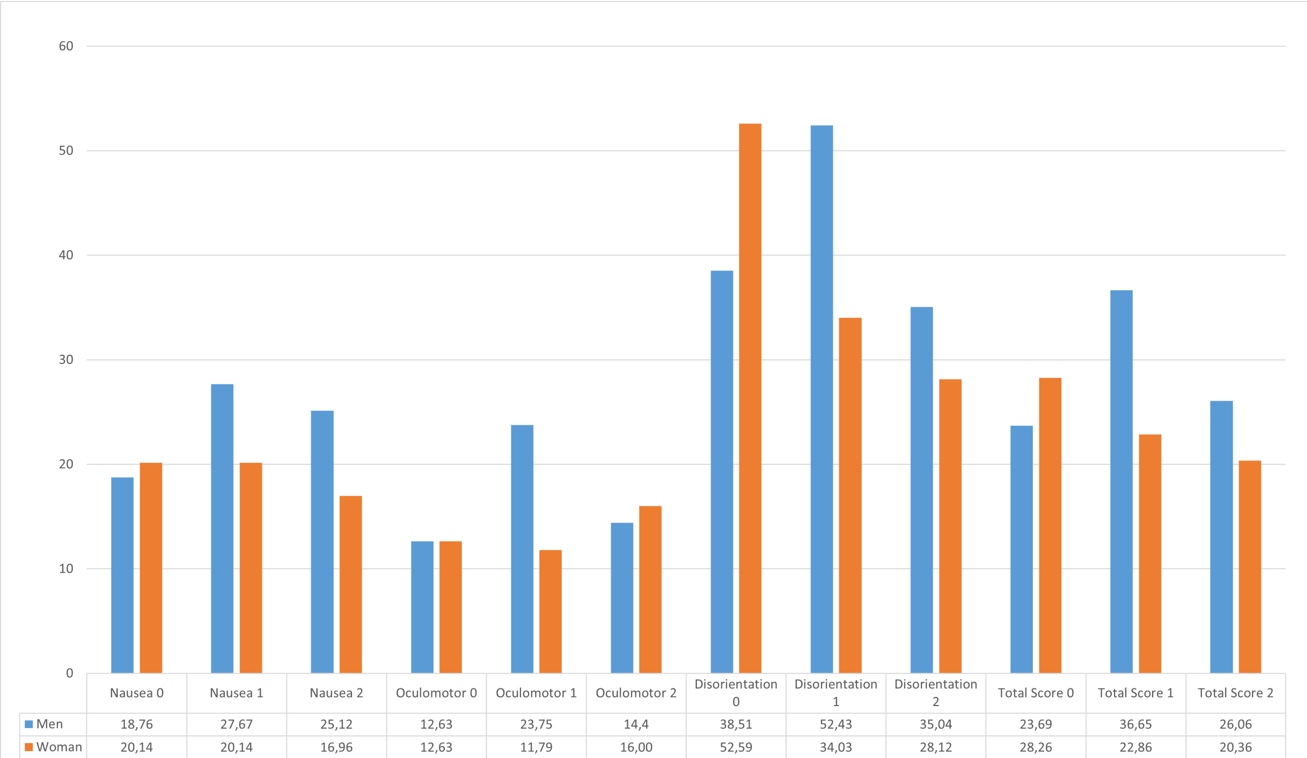


Figure 4.5: Average SSQ score for each scenario, comparing genders to each symptoms

4.1.1 Adaption among participants

A theory was discussed where participants could have experienced adaption (See chapter 2.3.2), making them less susceptible to simulation sickness in their last scenario. To investigate this, a sample of 8 participants experienced scenario 2 before scenario 1. 4 out of 8 finished all the scenarios, scoring a mean of 33.66 (SD = 28.61) in scenario 0, 39.27 (SD = 13.61) in scenario 1, and 33.66 (SD = 7.00) in scenario 2.
These scores are significantly higher than the average SSQ scores, which suggests that adaption did not occur within these participants. However, it is important to note that this was a limited sample (See figure 4.3.

Looking at the whole population, figure 4.3 also shows that the SSQ total score was lowest in scenario 2 and highest in scenario 1. Participants might have been accustomed to the virtual environment by scenario 2. However, the conditions changed drastically from scenario 0 to scenario 1, when motion was added. Which might explain the large increase in total SSQ scores. However, the total score goes down in scenario 2. Participants could have adapted themselves on the final test-scenario. Moreover, it is important to point out that the decrease in total SSQ scores could have been due to less discomforting motion in scenario 2. Especially "Disorientation" saw a significant decline from M = 48.9 (scenario 1) to M = 32.37 (scenario 2).

4.1.2 Correlation with SSQ and self reported probability of MS

An independent t-test was calculated in Microsoft Excel using "Probability of MS score" (POMS) (See section 4.6 and the total SSQ scores shown in figure 4.1. Even though all scenarios achieved a $\rho < 0.05$, the correlations were weak. Scenario 0 (r = 0.31) and scenario 2 (r = 0.21) had a positive correlation, although weak. Scenario 1 had a insignificant *negative correlation* (r = -0.12). This score is so low it can be disregarded. Scenario 0 and scenario 2 proves to have a correlation between SSQ and POMS, however the correlation is not strong, as the next section will illustrate and explain further.

Table 4.6 presents participants that scored highest on the POMS and SSQ total score in scenario 0. The left side of the table (blue) is sorted by SSQ total score, and the right side is sorted after POMS score (middle column). Looking at the right side (orange), those who reported a POMS of 9 have received varied SSQ scores (78.54 - 44.88). Additionally there is a large diversity amongst participants that reported 5 on POMS and their SSQ total score (86.02 - 7.48). The left side presents participant 30 and 16. Participant 16 had the second highest SSQ score of the study in scenario 0 (82.28), despite having a low POMS score (3). Although high POMS scores might result in higher SSQ scores, the correlation is weak, as the earlier independent t-test had shown. It is also fair to assume that the same dissimilarity can be found in the other scenarios as well. Which mirrors the findings in table 4.1.

Some reasons for this weak correlation could be that participants miss-interpreted the questions. When asked if they often get carsick, some participant might assume that they are driving themselves, where most people wont get carsick. An improved questionnaire would have asked more specifically if they often get carsick when riding as a passenger in the backseat. Moreover, being easily carsick might not even be correlated with simulation sickness.

Participant	Prone to MS	SSQ total score 0	Participant	Prone to MS	SSQ total score 0
30	5	86.02	43	9	78.54
16	3	82.28	48	9	44.88
43	9	78.54	23	7	56.1
54	4	71.06	30	5	86.02
45	5	67.32	45	5	67.32
9	3	67.32	34	5	56.1
53	3	63.58	14	5	44.88
27	3	59.84	25	5	41.14
23	7	56.1	47	5	29.92
34	5	56.1	36	5	29.92
7	3	52.36	46	5	26.18
48	9	44.88	39	5	18.7
14	5	44.88	41	5	11.22
6	3	44.88	33	5	11.22
25	5	41.14	26	5	7.48
AVG	**4.80**	**61.09**	**AVG**	**5.67**	**40.64**
SD	**2.01**	**13.84**	**SD**	**1.35**	**23.01**

Figure 4.6: On the left side (blue), top 15 participants that scored highest on the SSQ. On the right (orange) top 15 participants that scored highest on probability of MS score.

Self reported probability of MS			
Scenario	***N***	***p***	***r***
0	52	> 0.05	0.31
1	46	> 0.05	-0.12
2	45	> 0.05	0.21

Table 4.1: Correlation results from a dependent t-test with data from all participants.

4.1.3 Feedback during interviews

Responses in interview after completing scenario 0

In total 44 participants answered the post-scenario 0 (the motion platform turned off) questionnaire. Participants described symptoms and sensations that could be related to vection. Feelings of expected motion were expressed, one participant put it as "The body wanted to join in (on the motion)". Moreover, ten participants noted that accelerating, breaking and turning would make them unwell. Additionally, seven participants reported sensations that were categorized as "Unusual feelings". Interestingly, two test-drivers noted that any feelings of discomfort faded away or they got more accustomed to it over time while driving. Five participants reported not feeling any symptoms at all. Two said that they were either to focused or were having to much fun to notice. Whenever a participant would crash, the car tended to spin around and loose all of its momentum. 12 participants reported that loss of control made them unwell, this can be organized into crashing and spinning out. The participants reported feeling disorientated and attributed much of their nausea on the crashing and/or spinning out.

When asked about what the participants felt was missing, 16 expressed the lack of movement. 10 participants had negative feedback regarding the visuals, this include blurry vision and bad focus. One tester found the visuals very detailed. Regardless, participants noted that this made it hard to see the road from far away, which would cause crashes. Moreover, eight test-drivers expressed their wish for a map of some sort, and that this could prevent crashes as well.
When asked about the realism, most participants found it relatively realistic (M = 6.5, SD = 1.88, Min = 2, Max 10). And finally, all the participants were positive to the idea of using a driving simulator in driving education (Class B). When asked further, participants remarked that they could see simulator training for driving as a useful addition to the traditional method. These are some of the uses participants presented:

- Used as a stepping-stone for those more intimidated of driving.
- Used to learn rules such as traffic signs.
- Learn how to change gears in a manual car.
- Practice stressful situations such as driving on the highway or busy streets.

Responses in interview after completing scenario 1

44 participants were interviewed after completing scenario 1. Most feedback regarded braking in the simulation. It had nine negative responses to how the motion platform responded when braking. Most of it was that the motion platform was slow to react and did not give the right move or too little motion when a brake happened. Movement was also an issue among the participant where some responded to the movement saying it was wobbly, and some were comparing it with a boat.There was a high number (22) of participant that gave the feedback that they think it was fun (4),interesting (1) or realistic (17) as a sort of approval that they were happy with the simulation.

Responses in interview after completing scenario 2

In the interview after scenario 2, the respondents were mainly comparing their experience of the motion to the motion in scenario 1. Most of it was about the acceleration and braking of the car, where most was positive with the increased intensity. Compared to scenario 1, the car would still sometimes feel like a boat, where it would sway from side to side when driving straight, however this is more exaggerated in scenario 2. Three said that the car was harder to control with more intensity. But some also comment that it became easier to feel the speed and control the breaking when doing a turn. Changing gear would also jerk the platform that some took as unfavorable while others say it as something positive. There was only 11 compared to 17 after scenario 1 that said they found this realistic in the semi-structure interview, but this could mostly be due to that people only reported changes and did not repeat statement that have been said early assuming the interviewer already knew.

Delayed motion

Some participants in scenario 1 and scenario 2 would report on slow or delayed movements. One reason for this delay could be that the platform needs time to move. For instance, if the platform is tilted heavily to one side, and a motion requires it to move to the opposite side, then this would naturally cause delay.

4.1.4 The need for motion compensation

Motion compensation (See chapter 3.4.3) was clearly needed in scenario 1 and scenario 2. Without the motion compensation, participants took only seconds before being negatively affected by it. But this is not always the case according to Ng, Chan, and Lau [47], who conducted a study with cybersickness and sensory conflict theory using a motion-coupled virtual reality system. Their experiment found that compensating or canceling out the movement of the platform would cause higher SSQ scores. In fact, having the participant see the motion form the platform in-game was more preferable [47].
In the case of Ng, Chan, and Lau [47], their simulation did not have the expectation of the feeling of g-forces while driving a car. Their simulation was in a kitchen and having the room turn (See chapter 2.3.1).

4.2 Development of motion sickness over time

Using the fast motion sickness scale (FMS), data regarding motion sickness was taken each minute (10 minute per experiment) while the participant was driving. Taking the average FMS score for each minute, a graphs was plotted as seen in figure 4.7. The top graph (See figure 4.7) shows scenario 2 as clearly causing more discomfort, while scenario 1 is causing more discomfort than scenario 0 (See table 4.2 for the full data-sheet). Another importance is that scenario 0 and scenario 1 starts even, however scenario 0 starts to descend or stabilise and scenario 1 starts to ascend. This indicates that participants in scenario 0 got used to the experience over time, while the opposite happened for scenario 1. Looking at table 4.2, the FMS scores are higher at the 10 minute mark compared to the 1 minute mark. Interestingly, scenario 0 has a peak at the 6 minute mark and then descends before going up again at the 9 minute mark. This shows that some participants might have gotten accustomed to the virtual environment while driving as illustrated in graf 4.7. A similar dip can be seen in scenario 2 where minute 7 is lower than minute 6. This suggests that it is easier to get used to the virtual environment when there is no motion added.

It is important to keep in mind that the whole scale ranged from 0 to 20. Considering that 0 is "Feeling nothing" and 20 is "On the verge of puking". This means that in contrast to the while scale, the average scores for each scenario are on the lower side. Notably, these FMS results are not in line with the SSQ score. The FMS results suggests that scenario 2 causes most discomfort while the SSQ presents it is scenario 1. The next sections will try to investigate this discrepancy.

Total count = 39	FMS Mean development		
Min	Scenario 0	Scenario 1	Scenario 2
1	1.77	2.05	2.46
2	2.28	2.13	2.92
3	2.28	2.74	3.44
4	2.62	2.82	3.84
5	2.74	3.11	4.16
6	2.82	3.34	4.26
7	2.55	3.37	4.21
8	2.45	3.82	4.55
9	2.63	3.63	4.71
10	2.61	3.84	4.81
AVG	**2.48**	**3.09**	**3.94**
SD	**0.29**	**0.61**	**0.74**

Table 4.2: The average score for each minute for each scenario, along with total average and standard deviation

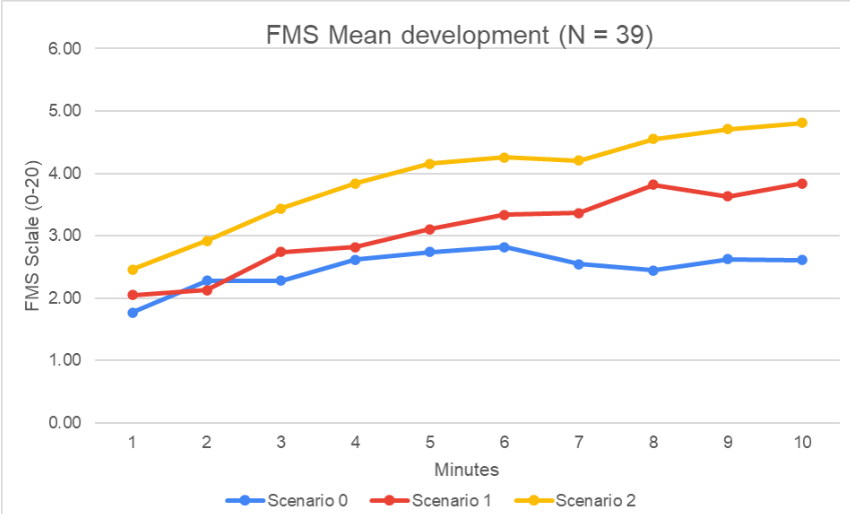


Figure 4.7: Average FMS score for each minute for each scenario: Top: Data from participants that finished all three scenarios (N = 39). Note that the FMS scale is from 0-20

4.2.1 Comparing FMS and SSQ score

The FMS and SSQ disagreed on which scenario caused the most discomfort. According to table 4.2 the average FMS results from scenario 0 had the lowest scores (M = 2.48, SD = 0.29), while scenario 2 scored the highest (M = 3.94, SD = 0.74). In contrast, the total scores from the SSQ (N = 39) presents scenario 1 as the highest scoring condition, followed by scenario 0 and scenario 2, respectively (See chapter 4.3).
To investigate why this difference occurred, a dependent t-test with all available data was calculated in Microsoft Excel (See section 3.8.2 for calculation method), to have as much data as possible. The results presents that there is indeed a correlation between the FMS and SSQ, shown in a correlation matrix in figures 4.8 4.3. This is similarly proved in other research , however, their results proved to be more correlated [60][37]. Nevertheless, all the scenarios for this research proved to have strong positive SSQ-total correlation, whereas scenario 1 had the lowest with r = 0.59 (See table 4.3 for more data) and scenario 2 had the strongest (r = 0.77). Investigating the sub-symptoms, scenario 2 had very strong correlations: SSQ-N 2 (Nausea) (r = 0.77), Disorientation (r = 0.84) and Oculomotor (r = 0.69). Interestingly, Oculomotor had the lowest correlation of all the sub-symptoms in both Somrak, Pogačnik, and Guna [60] and Keshavarz and Hecht [37]. In contrast, our study found that Oculomotor was not the lowest sub-symptom, even correlating more than Disorientation or Nausea, as seen in scenario 1 (See table 4.8).

Even though Somrak, Pogačnik, and Guna [60] used a VR-headset as well, their stimuli was not likely as fast paced as the racing game used in this study. The fast-paced game-play of Assetto corsa could have been more tiring on the eyes. Usage of different methods of stimuli could explain the discrepancy of FMS and SSQ correlation results. Keshavarz and Hecht [37] used a projector as stimuli which showed a first person view of a racing car driving around a track. Participants in Somrak, Pogačnik, and Guna [60] was seated and used a VR-HMD, where the main activity was maneuvering using the controllers. A motion platform was not used in any of the mentioned articles. This added motion from our motion platform could have influenced the participants interpretation during stimuli. For instance, participants could have experience less symptoms while receiving stimuli, and then gotten an increase when answering the SSQ (or reverse). This could apply more to the scenarios with added motion (Scenario 1 and Scenario 2), since the participant could have been influenced by the excitement or novelty of using the motion platform. This could also explain why the SSQ and FMS differed in which scenario caused the most discomfort. Additionally, there is more movement in scenario 2, this may cause initial surprise, causing participants to report higher FMS scores then usual. Participants could have misinterpreted the FMS. Though an explanation of the FMS was given before stimuli, some participants would report statement instead of concrete numbers. Moreover, the FMS requires the participants to examine their well being each minute, this could perhaps cause some participants to exaggerate or expect an increase in simulation sickness. The novelty and excitement of driving in a simulator could also have affected their self-reporting. Nevertheless, there seem to be a miss match between what participants felt while driving and what they reported afterwards, which could be the reason why FMS scenarios are different from the SSQ scenarios.

FMS and SSQ correlation			
Scenario	***Observations***	***p***	***r***
0	51	> 0.05	0.59
1	43	> 0.05	0.64
2	43	> 0.05	0.77
Sub-symptoms			
Nausea	***p***		***r***
SSQ-N 0	> 0.05		0.62
SSQ-N 1	> 0.05		0.57
SSQ-N 2	> 0.05		0.73
Disorientation			
SSQ-D 0	> 0.05		0.42
SSQ-D 1	> 0.05		0.58
SSQ-D 2	> 0.05		0.76
Oculomotor			
SSQ-O 0	> 0.05		0.45
SSQ-O 1	> 0.05		0.60
SSQ-O 2	> 0.05		0.64

Table 4.3: Correlation table for SSQ and FMS. The sub-symptoms are divided in order Nausea, Disorientation and Oculomotor.

N = 51	*FMS Average 0*	*SSQ 0*	*Neusea 0*	*Oculomotor 0*	*Disorientation 0*
FMS Average 0	1				
SSQ 0	0.59	1.00			
Neusea 0	0.62	0.79	1.00		
Oculomotor 0	0.45	0.89	0.54	1.00	
Disorientation 0	0.42	0.88	0.51	0.75	1

N = 43	*FMS Average 1*	*SSQ 1*	*Neusea 1*	*Oculomotor 1*	*Disorientation 1*
FMS Average 1	1				
SSQ 1	0.64	1			
Neusea 1	0.57	0.87	1		
Oculomotor 1	0.60	0.92	0.67	1	
Disorientation 1	0.58	0.93	0.72	0.81	1

N = 43	*FMS Average 2*	*Total Score 2*	*Neusea 2*	*Oculomotor 2*	*Disorientation 2*
FMS Average 2	1				
Total Score 2	0.77	1			
Neusea 2	0.73	0.92	1		
Oculomotor 2	0.64	0.92	0.74	1	
Disorientation 2	0.76	0.93	0.78	0.86	1

Figure 4.8: A correlation matrix for FMS, SSQ total scores, nausea, oculomotor and disorientation.

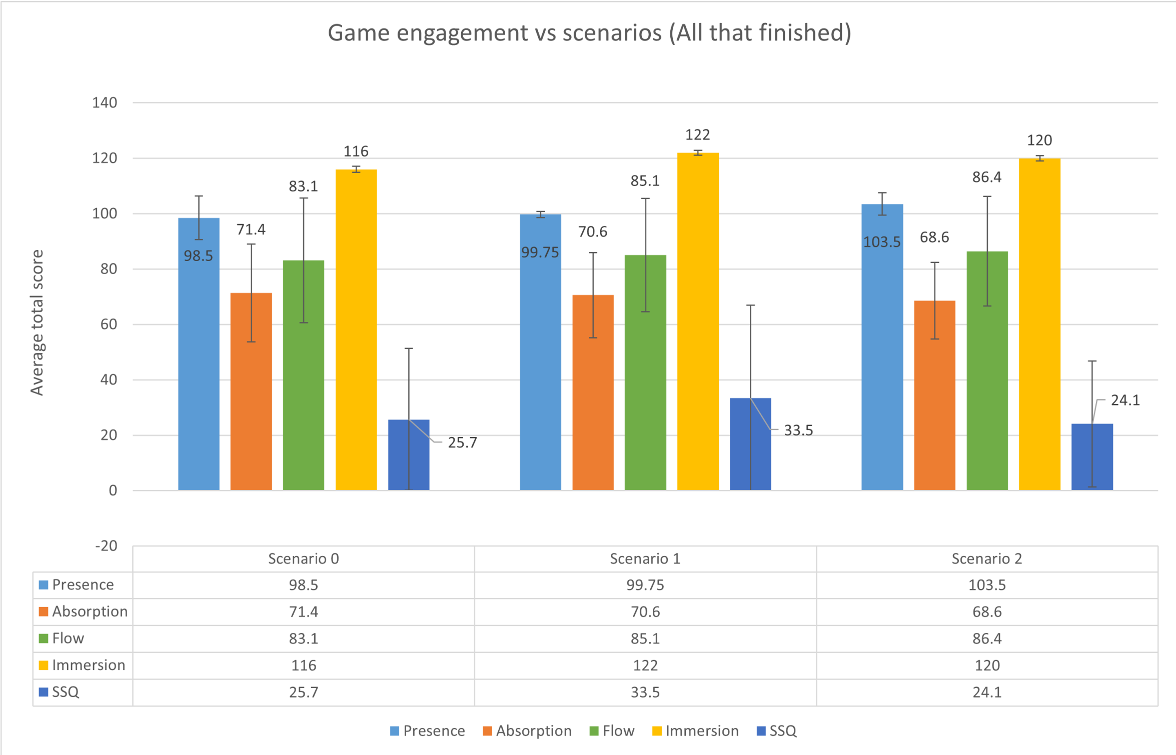


Figure 4.9: Using only data from participants who finished all three scenarios and the SSQ. The data is divided up by Presence, Absorption, Flow and Immersion - along with the total SSQ scores and standard deviation.

4.3 Engagement and immersion during simulation

The Game engagement questionnaire (GEQ) measures game engagement that include presence, absorption, flow and immersion. A calculation with only participants who finished all three scenarios *and* answered all three GEQ questionnaires were taken into account (N = 24). The number of participants are lower because the GEQ was introduced later in the study. Figure 4.9 presents no significant difference between the scenarios. However, there i still a similar trend where scenario 0 has a lower average than scenario 1 and 2 (See table B.6 for dataset). Moreover, despite the increase in total SSQ scores from scenario 0 to scenario 1, the GEQ seems to remain the, even slightly increasing. This suggests that simulation sickness might not effect game engagement all too much. A rasch analysis was calculated and the relevant results are shown in table 4.5. Remember that figure 3.15 presents a total score of 75 with a measure of 50.01 as the average. With that in mind, the results from table 4.5 put all the scenarios just below average, with scenario 2 scoring the highest (M = 69.75, Measure = 50.08). To investigate correlation, a dependent t-test (See this chapter for explanation 3.8.2) was calculated in Microsoft Excel using the same participants (N = 24) Interestingly, scenario 0 and 1 proved to have a weak negative correlation (r < -0.4) between GEQ and SSQ scores. Scenario 2 presented a weak positive correlation (r = 0.0028). A negative correlation means that when one variable decreases, then the other increases (and reverse). The dependent t-test shows that the negative correlated scenarios had a $\rho < 0.05$. See table 4.4 for dataset. The r of scenario 2 is so low that it can be disregarded, meaning that there was no correlation between the SSQ and GEQ in scenario 2. The correlations for scenario 0 and scenario 1 however, although weak, presents a negative correlation. If the SSQ goes down, then the GEQ goes up (and reverse).

35 people answered the GEQ for scenario 0, 43 for scenario 1 and 44 for scenario 2. A rasch analysis was conducted to find total scores and measures for each scenario which are presented in graph 4.10. The graph shows no significant difference between the three scenarios. All three scenarios performed reasonably, considering that a total score of 71 and measure of 50.12 is roughly the median on the table of measures (See table 3.14). With that in mind, scenario 2 scored the highest average in both total score (M = 68.3, SD = 11.1) and measure (M = 49.43, SD = 4), but again, not a significant difference. See table 4.11 for the full data-table.

A more detailed perspective is achieved by dividing up the data into their respective measure-

GEQ and SSQ correlation			
Scenario	***Observations***	***ρ***	***r***
0	24	> 0.05	-0.319
1	24	> 0.05	-0.368
2	24	> 0.05	0.003

Table 4.4: Presents the correlation scores for the GEQ and SSQ.

	Scenario 0, N = 24	Scenario 1, N = 24	Scenario 2, N = 24
Total Score Average	66.52	68.27	69.75
Measure Average	47.48	47.67	50.08
Standard deviation Score	10.01	11.23	7.18
Standard deviation Measure	3.16	3.94	2.39

Table 4.5: Presents the total scores and measure scores with standard deviation of the 24 participants that completed all three scenarios.

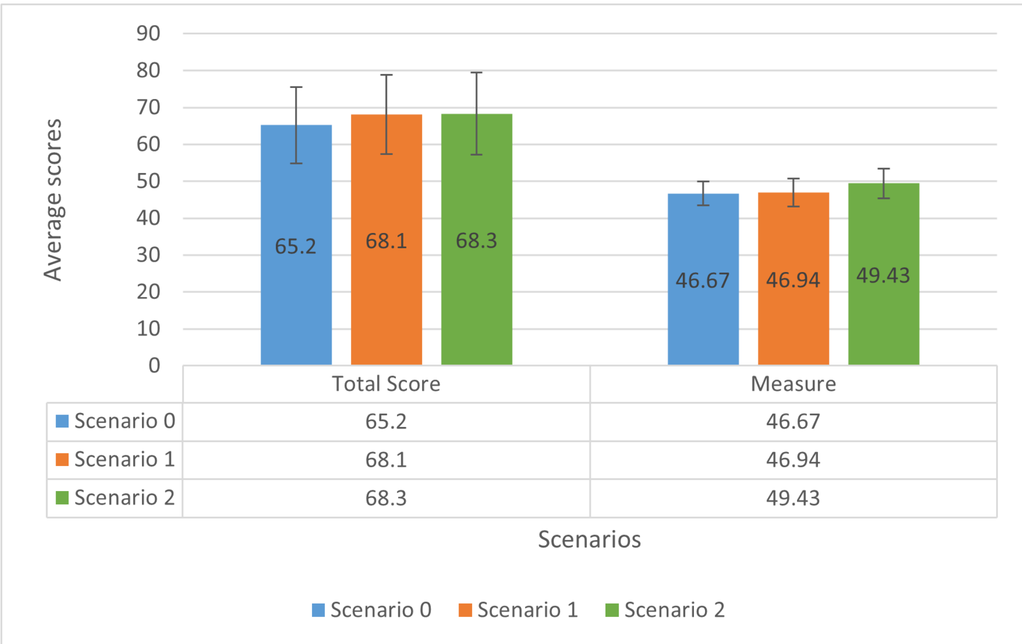


Figure 4.10: Compares the total score and measure between the scenarios

	Scenario 0, N = 35	Scenario 1, N = 43	Scenario 2, N = 44
Total Score	65.2	68.1	68.3
Measure	46.67	46.94	49.43
Count	35	43	44
Standard deviation Score	10.3	10.7	11.1
Standard deviation Measure	3.2	3.72	4

Figure 4.11: Presents the total score and measure for all three scenarios, including standard deviation.

ments: Figure 4.13 presents the GEQ data divided into its four area of measurements. It is important to note that this calculation used the data from all the participants, even those who only participated once. Overall game engagement scores where higher in both scenario 1 and 2, compared to scenario 0. All game engagement measurements increased by a minimum of 19% from scenario 0 to scenario 1, where absorption had the lowest increase (19.85%) and immersion had the highest (28.31%). This is a significant increase compared to the previous calculation with all the finished. A theory can be that those who did not choose to continue due to for example simulation sickness, rated the GEQ poorly. See table 4.13 for the full dataset.

To investigate for correlation between presence and simulation sickness, three scatter graphs were created as shown in figure 4.12. This calculation took into account all respondents (See calculation B.5), even those who only finished one scenario. Interestingly, only scenario 1 ($p = 0.003$, $r = -0.45$) shows a negative correlation between MS and presence, though a weak-medium one. Scenario 0 ($p > 0.05$, $r = -0.42$) and scenario 2 ($p > 0.05$, $r = -0.21$) could not disprove the null hypothesis. A common theme through all three scenarios, is the disparity of the responses. For instance, scenario 1 shows five respondents who scored 20 on presence, with a SSQ score that varies from 0 to almost 80.
It is important to keep in mind that the GEQ measures four different perimeters. This might mean that a specific measurement will not capture the true meaning of the parameters. More specialized questionnaires that targets for example presence in of itself would be better.

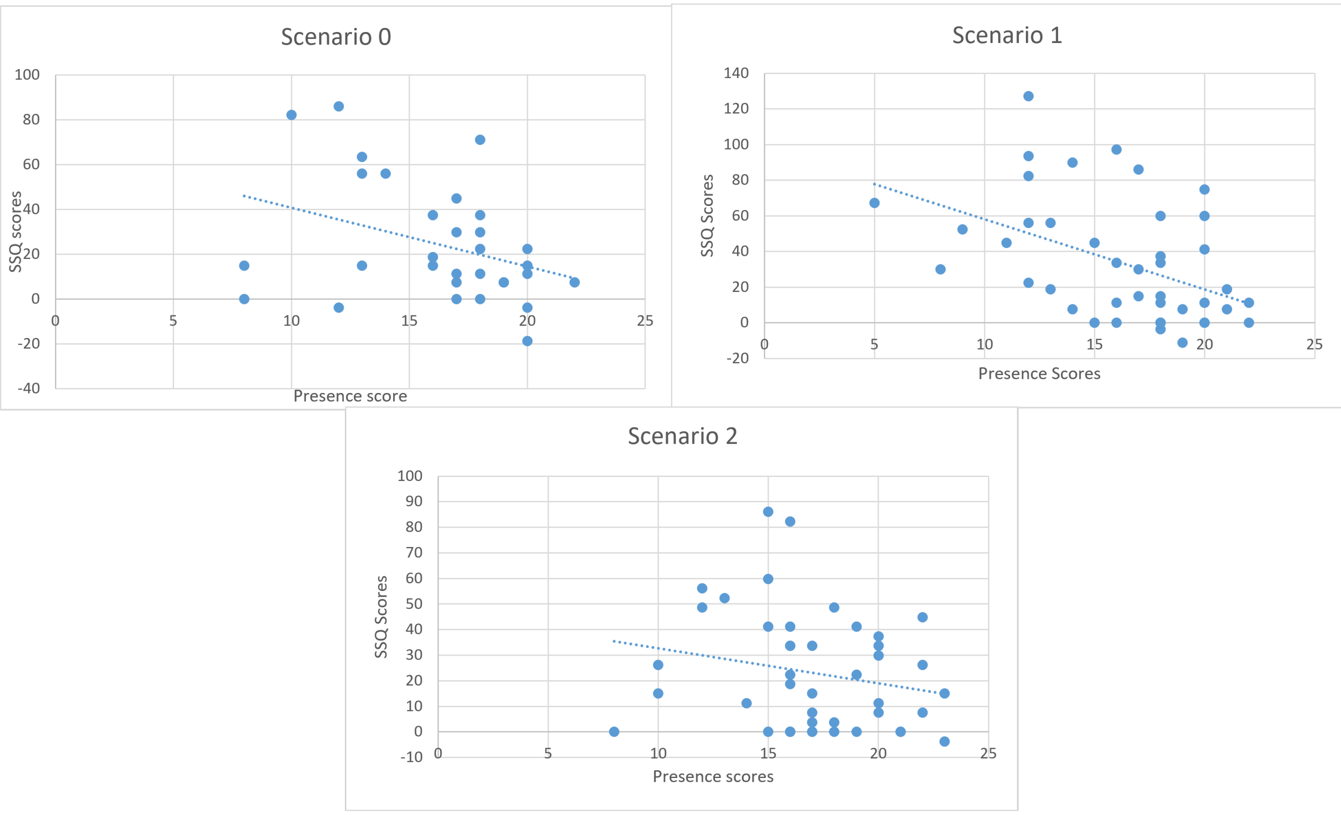


Figure 4.12: Correlation between perceived presence (sub-measurement of GEQ) and motion sickness.

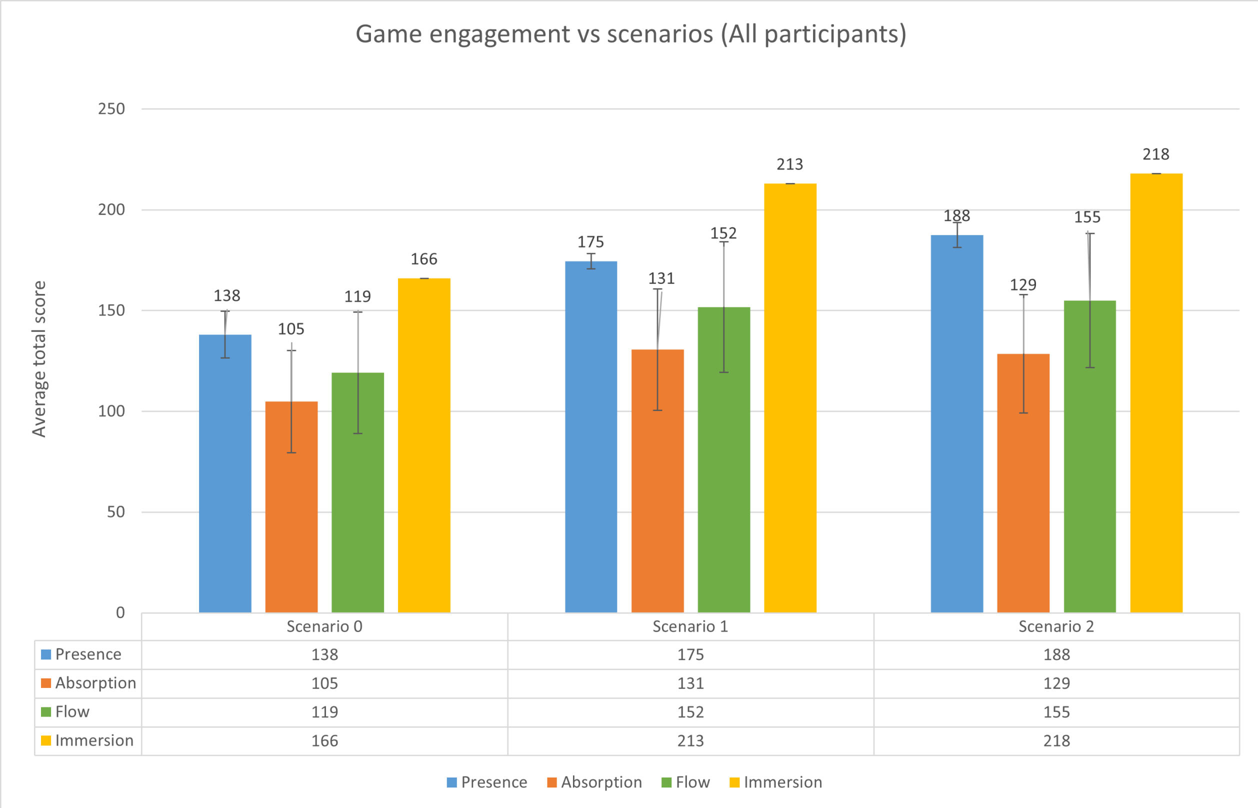


Figure 4.13: Displays the SSQ and the four measurements in the GEQ compared after scenarios

4.3.1 Realism

The participant were asked a question in the post interview (See appendix interview A.2) about how they experienced the realism regarding the simulation for each scenario. The scale was 1-10, where the mean of scenario 1 was highest with 7.68 of 10, even though this scenario cause most motion sickness(See chapter 4.1).

4.3.2 Absorption did not correlate

In the GEQ, all the measurements followed the pattern of ascending for each scenario except absorption. But the question for absorption may have caused confusion, for example the question "Time seems to kind of stand still or stop". This question could be "strongly agreed" upon even if a participant was negative, as in "Time seems to kind of stand still or stop because i was bored". This question scored 143 in scenario 1 while 115 in scenario 0 and 118 in scenario 2, making it so that absorption got a high score in scenario 1 130.6 (SD = 30.0) (See table 4.6). This is the only question that does not follow the same pattern as the rest. If we put the score of "Time seems to kind of stand still or stop" in scenario 1 down to 118, like scenario 2 it absorption doesn't score more than 124.4 (SD = 28.8), placing it lower than scenario 2, making it so that the GEQ scored highest in scenario.

	Scenario 0	Scenario 1	Scenario 2
SSQ			
SSQ Answers	47	43	42
AVG	25.7	33.49	24.13
SD	25.60	33.53	22.72
GEQ Answers	35	43	44
Absorption			
I feel scared	56	71	76
I lose track of where I am	111	140	143
I feel different	130	150	156
Time seems to kind of stand still or stop	115	149	118
I feel spaced out	112	143	150
Average score	104.8	130.6	128.6
SD	25.3	30.0	29.3
Flow			
I don't answer when someone talks to me	76	100	100
I can't tell if I'm getting tired	108	146	150
If someone talks to me, I don’t hear them	93	113	113
I feel like I just cant stop playing	114	156	165
The game feels real	137	190	190
I get wound up	169	192	207
Playing seems automatic	131	185	181
I play without thinking about how to play	125	162	154
Playing makes me feel calm	86	122	134
AVG	119.1	151.8	154.9
SD	30.1	32.3	33.3
Presence			
Things seem to happen automatically	121	172	192
My thoughts go fast	146	180	180
I play longer than I meant to	134	170	195
I lose track of time	151	176	183
AVG	138	174.5	187.5
SD	11.6	3.8	6.2
Immersion			
I really get into the game	166	213	218
AVG	166	213	218
SD	0	0	0

Table 4.6: Data used in figure 4.13. The table shows the GEQ divided into 4 measurements including the SSQ.

4.4 Challenges and Limitations

4.4.1 Data collection

Simulator sickness questionnaire scales

The SSQ is supposed to present four alternatives to respondents: "none = 0 ", "slight = 1", "moderate = 2" and "severe = 3". However, at the start of the experimentation, a simplified SSQ survey instrument with only three alternatives was used: "none = 0 ", "moderate = 1" and "severe = 2". This issue affected 18 participants in scenario 0, 12 in scenario 1 and 4 in scenario 2, resulting into higher scores given that the scale was from 0 to 2 instead of 0 to 3. After preliminary data analysis, and the fact that respondents expressed their symptoms at more varying degrees of intensity, the SSQ instrument was updated with the four scales: "none = 0 ", "slight = 1 ", "moderate = 2 " and "severe = 3 ". The following section will attempt to give reasons for keeping the dataset:

We present three data groups with their calculations:

- All of the participants that finished all three scenarios (N = 39). This group includes the 18 participants with the missing option.
- Excluding the 18 participants (N = 21). This group excludes the 18 participants the had the missing option.
- Missing option group (N = 18).

The common theme within these groups is that scenario 2 has lower SSQ total scores than scenario 1. The biggest difference is in the group excluding the 18 participants (N = 21) where scenario 0 scored the lowest in SSQ. However, scenario 2 still had lower SSQ total scores than scenario 1. Calculations with only the 18 participants had their highest SSQ total scores in scenario 1 (M = 43.43, SD = 37.17), this average is significantly higher than the average in "All the participants" (M = 34.24). Investigating deeper into the "only 18 participants" group, scenario 1, a participant stands out by having a considerably higher SSQ score than the rest in his group with a SSQ total score of 127.16. This participant had only missed the "slight" option in scenario 0, the rest of the scenarios had the correct options, including scenario 1. In theory, if this participant was removed, the average score would decrease to M = 38.50. Still higher than the average of the "all of the participants" group, however still in a reasonable spectrum. in conclusion, even with the missing option in the "Missing option" group, the average SSQ total score were still in line with the other groups (See table 4.7. Scenario 1 in "The missing option" group has a higher average than the rest (M = 43.43), this can be reasoned with one participant that scored higher than average, which is also reflected by the high standard deviation (SD = 37.17). Moreover, the research question concerned if a motion platform helped with reducing simulation sickness. All three data groups suggests that scenario 2 induces less simulation sickness compared to scenario 1. Lastly, if the study were to exclude the participants in the "Missing option" group, this would severely impact the number of dataset, reducing it from 39 to 21 of participants that finished all three scenarios. With that said, all the following calculations in this thesis are presented with the 18 participants that had the missing option (See results in table B.3).

Number of particpent	39	21	18
	All the participants	Excluding 18 first participants	Missing option
	Mean		
Total Score 0	25,13	24,58	25,76
Total Score 1	34,24	26,36	43,43
Total Score 2	23,69	25,65	21,4
	Standard deviation		
Total Score 0	27,25	29,69	24,07
Total Score 1	32,81	26,08	37,17
Total Score 2	23,08	26,02	18,82

Table 4.7: Comparing average total scores and standard deviation between "All of the participants, "Excluding the 18 participants" and "Only the 18 participants".

4.4.2 Technical issues

Motion compensation failing

The motion compensation tool (See chapter 3.4.3) did not always work and would, in mid testing, suddenly stop working, making the participant move inside the simulation according to the motion platform movements making a nauseating experience. This became a more common occurrence issue later on, and the motion compensation was more heavily monitored towards the end. Because of this, some of our participants may have had a worse experience than the test was planning. And may have impacted both SSQ and GEQ results. Some attempted solutions were to restart the PC, re-installing the motion-compensation software and changing controllers. However, none of these solution worked permanently.

HMD losing connection the to base station

The base station sometimes had an issue finding the HMD (See chapter 3.3.4) and making the participant get a grey display or dislocate their viewport out of the driver seat. this may also impact both SSQ and GEQ results. This could affect the GEQ more than the SSQ, since these errors were faster to recover from and didn't give the participant an active nauseating experience as motion compensation tool failing did.

4.4.3 User-based testing amidst Covid-19 Pandemic

These tests were done under the covid-19 pandemic, adding a level of disinfection that we need to follow (See chapter 3.7.2), making it a requirement to disinfect everything.

Disinfection smell

VR-HMD, due to it being disinfected by antibacterial after each use, gave an evident smell of this substance, which some participants found nauseating.

Couldn't go near the participant

Due to covid rules, we couldn't go near the participant since we had to stay the distance from the participant according to the municipality rules. Participants had to adjust their own headset, making some of them not having the HMD correctly fasten and ending up disturbing their experience.

Chapter 5

Conclusions

This research project started with Align Racing reaching out, saying they were interested in the possibilities of VR simulations for training purposes. As we have an interest in VR, we reached out and heard what they needed. Align Racing was looking for a simulation where their drivers could train with their cars in different states, such as stiff versus soft suspensions. We were planning to make them a driving simulation to see the effects on simulation sickness and training. Over many meetings and discussions, there was made a plan modify an already existing racing-simulator (Asseto Corsa), using input and experience from the Align racing drivers, to create a similar experience in a virtual simulated environment as possible. Later we got access to a 3D model of their newest car that was still in development The 3D model was made drive-able in Asseto Corsa (See chapter 3.1). Having a motion platform could bring a new perspective to the research, where there is currently little prior research on simulation sickness using a commercial motion platform with virtual reality. A motion platform could also in theory provide more immersion and reduce simulation sickness (See chapter 2.3.1). After receiving a motion platform, we notice that simulation sickness was a more challenging and pressing issue than what Align racing initially requested. There were limited research on high-speed racing in VR with a commercial motion platform that investigated effects on simulation sickness. The research proceeded with the idea of mapping out where the illness occurred, when it happened, who was affected and how much they were effected. Additional research was also conducted regarding game engagement.

Our participants were given three conditions (scenarios) one with no motion(scenario 0) and two with motion(scenario 1 and 2). Scenario 1 had moderate motion (35 out of 100) and scenario 2 had increased motion (75 out of 100)(See chapter 3.7.1)

The methods that was used to gather the information were SSQ, FMS, GEQ. SSQ and FMS was used to measure participants simulation sickness symptoms, while GEQ was for measuring participants engagement. The results points us to the following conclusions:

According to our results, we are able to conclude that added motion can both be negative and positive for simulation sickness. For instance, where scenario 1 would cause more simulation sickness than scenario 0. Moreover, there are some trends that are interesting. Women, for example, seems to get less symptoms with more motion. Results show that women on average scored highest on the SSQ in scenario 0 and lowest on scenario 2. Nevertheless, we must emphasise that the test-pool for women was not high enough to draw any definite conclusions.

Overall, scenario 1 caused the most simulation sickness based on the SSQ scores. Scenario 2 had the lowest SSQ score. This tells us that less intense movements (scenario 1) *on average*, is more nauseating than more intense movements (scenario 2).

Other elements might also increased the average SSQ score. One hypothesis may be that the motion platform did not deliver accurate enough motion as the participants expected. From the results of the post interview, participants reported unexpected motions regarding accelerating, braking and turning. For instance, some participants in scenario 1 would report delayed reactions from the platform when braking or accelerating (See chapter 4.1.3). Another influence could be the antibacterial used to clean the equipment. This left an odour that would make some participants nauseous (See chapter 4.4.3). Other sources that could have influence is when the motion compensation failed (See chapter 4.4.2). This failure would cause temporary discomfort that could influence the rest of the driving-period. Sometimes players would fall through the world or the screen would turn gray (See chapter 4.4.2) due to the disconnection of the HMD to the base stations. This could cause discomfort or break the immersion.

A small investigation was done to test for virtual reality adaption. 4 participants finished all three scenarios where they received scenario 2 before scenario 1. This experiment could not prove any adaption, indeed these participants scored higher than the overall average. However, as seen in the whole population, participants SSQ score went drastically up from scenario 0 to scenario 1. But then lowered significantly in scenario 2. One theory for this could be that participant would have adapted themselves to the simulation.

The Fast motion sickness scale was used to measure simulation symptoms each minute while the participant was driving. This method proved to be correlating with the SSQ, however it did produce other results. This discrepancy could be due to some reasons. The motion could have exaggerated and influence the participants reporting, making them report higher than reality. Since the participant had to self evaluate their symptoms for simulation sickness each minute, this could also have led to increased simulation sickness through bias.
Added motion increased engagement among participants. With the calculation of those who completed all the scenarios (N =24), the results from the GEQ showed that scenario 1 and 2 on average scored higher than scenario 0. This was especially true with calculations using all available data. Moreover, GEQ did not decrease when SSQ increased. Indeed a no significant correlation was proven between SSQ and GEQ. Additionally, participants would express excitement in the post-test-interviews, explaining that they preferred motion over stationary.
The goal of the experiment was to investigate if added motion leads the less simulation sickness. Results from scenario 1 presented that added motion might increase simulation sickness. However, scenario 2 had the lowest overall total SSQ scores. Interestingly, disorientation was the most affected symptom. Disorientation scores went down dramatically from scenario 1 to scenario 2. In this experiment, out of the scenarios with motion, scenario 2 seems to be the least disorientating scenario.

This thesis has presented a research environment for testing and measuring of simulation sickness and Game engagement. Firstly, the commercial platform was easy to setup and use. However, combining the motion platform to a virtual reality headset in an acceptable way required an additional software fore motion compensation. This software proved to work most of the time, however, more reliable methods would be preferable. The FMS worked well, however it did not correlate as expected with the SSQ. This could be due to the test environment with the motion platform. The GEQ also worked well to capture the engagement of the participants, however more niche questionnaires could be adopted to measure specific areas.

5.1 Further work

Both feedback and the result shows there was something preferable in each scenario and some parts that are worse. Examples of this is that the participant said they like the high intensity of braking, but people complain about movement when driving strait.
Therefore, a more in-depth investigation could be conducted in the future with a smaller user group of participants that are most negatively affected by simulation sickness to partake in several more tests. Then use SimTools[58] and investigate what motion that causes simulation sickness. Making every movement of the platform be as motion friendly and/or realistic as possible to further investigate the sensory conflict theory. Then a set of parameters can be developed that help and worsen simulation sickness instead of overall set power on the motion platform.

Technical issues like motion compensation failing (See chapter 4.4.2) and HMD losing connection to the base station (See chapter 4.4.2) was an unnecessary distraction and may have resulted in impacting our final result. A more stable technical solution would be preferable. Further technology development of motion compensation and HMD connectivity level would be ideal.

Bibliography

[1] Liva Abele and Mette Møller. *Driver training in a simulator. Improved hazard perception.* English. DTU Management, 2018.

[2] Actuonix Motion Devices. *Servo Actuators vs. Linear Actuators - What's The Difference?* [Online; accessed May, 2021]. Apr. 2020. URL: http://blog.actuonix.com/2017/05/whats-difference-between-linear.html.

[3] Ai. *Powered by AI: Oculus Insight.* [Online; accessed March, 2021]. 2021. URL: https://ai.facebook.com/blog/powered-by-ai-oculus-insight.

[4] Per Backlund, Henrik EngstrÃ¶m, Mikael Johannesson, and Mikael Lebram. "Games for traffic education: An experimental study of a game-based driving simulator." In: *Simulation & Gaming* 41.2 (2010), pp. 145–169. DOI: 10.1177/1046878107311455. eprint: https://doi.org/10.1177/1046878107311455. URL: https://doi.org/10.1177/1046878107311455.

[5] Carey D Balaban and Bill J Yates. "What is nausea? A historical analysis of changing views." In: *Autonomic Neuroscience* 202 (2017), pp. 5–17.

[6] Lawrence Barretto. *'You get the same buzz as racing for real' —Lando Norris on the thrill of sim racing: Formula 1®.* Apr. 2020. URL: https://www.formula1.com/en/latest/article.you-get-the-same-buzz-as-racing-for-real-lando-norris-on-the-thrill-of-sim.1FM26RLpKxViWXTYwSz0J.html.

[7] Andy Bauman. *(3) SteamVR's "Lighthouse" for Virtual Reality and Beyond - YouTube.* Youtube. 2021. URL: https://www.youtube.com/watch?v=xrsUMEbLt0s.

[8] P. Bimberg, T. Weissker, and A. Kulik. "On the Usage of the Simulator Sickness Questionnaire for Virtual Reality Research." In: *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW).* 2020, pp. 464–467. DOI: 10.1109/VRW50115.2020.00098.

[9] A C Bittner and J.C. Guignard. "Shipboard Evaluation of Motion Sickness Incidence and Human Engineering Problems." In: *Journal of Low Frequency Noise, Vibration and Active Control* 7.2 (1988), pp. 50–65. DOI: 10.1177/026309238800700202. eprint: https://doi.org/10.1177/026309238800700202. URL: https://doi.org/10.1177/026309238800700202.

[10] Patricia Bockelman and Deanna Lingum. "Factors of cybersickness." In: *International Conference on Human-Computer Interaction.* Springer. 2017, pp. 3–8.

[11] William J. Boone, John R. Staver, and Melissa S. Yale. *Rasch Analysis in the Human Sciences.* Dordrecht, Heidelberg, New York, London: Springer, 2014.

[12] Shashidhara BP, Chandra Sekaran, Yashpal Bhatia, Magesh Kumar, Binesh Kumar, and Hemanth Kumar. "Development of a Full Mission Simulator for Pilot Training of Fighter Aircraft." eng. In: *Defense science journal* 68.5 (2018), pp. 425–431. ISSN: 0011-748X.

[13] Jeanne H. Brockmyer, Christine M. Fox, Kathleen A. Curtiss, Evan McBroom, Kimberly M. Burkhart, and Jacquelyn N. Pidruzny. "The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing." In: *Journal of Experimental Social Psychology* 45.4 (2009), pp. 624–634. ISSN: 0022-1031. DOI: https://doi.org/10.1016/j.jesp.2009.02.016. URL: https://www.sciencedirect.com/science/article/pii/S0022103109000444.

[14] Rick Broida. *Amazon Black Friday 2020 deals are here: These are the top picks.* Nov. 2020. URL: https://www.cnet.com/news/amazon-black-friday-2020-deals-are-here-these-are-the-top-picks/.

[15] Cambridge-Dictionary. *Wound up Definition.* 2021. URL: https://dictionary.cambridge.org/dictionary/english/wound-up (visited on 05/27/2021).

[16] Shi Cao, Krithika Nandakumar, Raiju Babu, and Benjamin Thompson. "Game play in virtual reality driving simulation involving head-mounted display and comparison to desktop display." In: vol. 24. 3. Sept. 2020, pp. 503–513. DOI: 10.1007/s10055-019-00412-x. URL: https://doi.org/10.1007/s10055-019-00412-x.

[17] Simon Davis, Keith Nesbitt, and Eugene Nalivaiko. "A Systematic Review of Cybersickness." In: *Proceedings of the 2014 Conference on Interactive Entertainment.* IE2014. Newcastle, NSW, Australia: Association for Computing Machinery, 2014, pp. 1–9. ISBN: 9781450327909. DOI: 10.1145/2677758.2677780. URL: https://doi.org/10.1145/2677758.2677780.

[18] Marc Dingman. "Know Your Brain: Vestibular System —Neuroscientifically Challenged." In: (2015). [Online; accessed May, 2021]. URL: https://www.neuroscientificallychalle com/blog/know-your-brain-vestibular-system.

[19] William Alexander Newman Dorland. *Dorland's illustrated medical dictionary.* WB Saunders, 1925.

[20] Johannes Drosdol and Ferdinand Panik. "The Daimler-Benz driving simulator a tool for vehicle development." In: *SAE Transactions* (1985), pp. 981–997.

[21] Dschadu. *OpenVR Motion Compensation.* Mar. 2021. URL: https://ovrmc.dschadu.de.

[22] Natalia Dużmańska and Agnieszka Strojny Pawełand Strojny. "Can Simulator Sickness Be Avoided? A Review on Temporal Aspects of Simulator Sickness." In: *Frontiers in Psychology* 9 (2018), p. 2132. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2018.02132. URL: https://www.frontiersin.org/article/10.3389/fpsyg.2018.02132.

[23] Even Management. *Project Next Generation.* [Online; accessed May, 2021]. Dec. 2019. URL: https://www.evenmanagement.no/even-esport.

[24] Epic Games. *Features.* Mar. 2021. URL: https://www.unrealengine.com/en-US/features.

[25] Alireza Mazloumi Gavgani, Keith V. Nesbitt, Karen L. Blackmore, and Eugene Nalivaiko. "Profiling subjective symptoms and autonomic changes associated with cybersickness." In: *Autonomic Neuroscience* 203 (2017), pp. 41–50. ISSN: 1566-0702. DOI: https://doi.org/10.1016/j.autneu.2016.12.004. URL: https://www.sciencedirect.com/science/article/pii/S1566070216301096.

[26] Gforcefactory. *Gforcefactory B.V., Utrecht, Netherlands.* [Online; accessed Feburary, 2021]. 2021. URL: https://www.gforcefactory.com/.

[27] GregorDS. *The six degrees of freedom three dimensions and three rotations. The texts are located on the positive direction according to the right hand rule.* [Online; accessed Mars, 2021]. 2015. URL: https://commons.wikimedia.org/wiki/File:6DOF.svg?fbclid=IwAR3chKQRdQ87U3zFrQxET4C0wEFrQ_4h-_UiMGN9vfPhB_hijovTe5yb6tk#filelinks.

[28] Stefan Groot, Joost de Winter, Max Mulder, and Peter Wieringa. “Car Racing in a Simulator: Validation and Assessment of Brake Pedal Stiffness.” In: *Presence Teleoperators and Virtual Environments* 20 (Feb. 2011), pp. 47–61. DOI: 10.1162/pres_a_00033.

[29] Tom Harris. *How Joysticks Work*. June 2002. URL: https://electronics.howstuffworks.com/joystick8.htm.

[30] Gordon Holmes. “Disturbances of visual orientation.” In: *The British journal of ophthalmology* 2.9 (1918), p. 449.

[31] Quinate Ihemedu-Steinke, Rainer Erbach, Prashanth Halady, Gerrit Meixner, and Michael Weber. “Virtual Reality Driving Simulator Based on Head-Mounted Displays.” In: Feb. 2017, pp. 401–428. ISBN: 978-3-319-49447-0. DOI: 10.1007/978-3-319-49448-7_15.

[32] Autodesk Inc. *3D modeling and rendering software for design visualization, games, and animation*. Mar. 2021. URL: https://www.autodesk.com/products/3ds-max/overview?term=1-YEAR.

[33] Harvey J. Irwin. “Pathological and Nonpathological Dissociation: The Relevance of Childhood Trauma.” In: *The Journal of Psychology* 133.2 (1999). PMID: 10188264, pp. 157–164. DOI: 10.1080/00223989909599730. eprint: https://doi.org/10.1080/00223989909599730. URL: https://doi.org/10.1080/00223989909599730.

[34] Ph.D Jason Jerald. *The VR Book: Human-Centered Design for Virtual Reality*. ACM Books. Morgan & Claypool Publishers, 2016. ISBN: 978-1-97000-113-6.

[35] Christopher Joyce, Patrick H Le, and Diana C Peterson. “Neuroanatomy, Cranial Nerve 3 (Oculomotor).” In: *StatPearls [Internet]* (2019).

[36] Robert S. Kennedy, Norman E. Lane, Kevin S. Berbaum, and Michael G. Lilienthal. “Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness.” In: *International Journal of Aviation Psychology* 3.3 (1993), p. 203. ISSN: 10508414. URL: http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=7369844&site=ehost-live.

[37] Behrang Keshavarz and Heiko Hecht. “Validating an efficient method to quantify motion sickness.” In: *Human factors* 53.4 (2011), pp. 415–426.

[38] Hyun K. Kim, Jaehyun Park, Yeongcheol Choi, and Mungyeong Choe. “Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment.” In: *Applied Ergonomics* 69 (2018), pp. 66–73. ISSN: 0003-6870. DOI: https://doi.org/10.1016/j.apergo.2017.12.016. URL: https://www.sciencedirect.com/science/article/pii/S000368701730282X.

[39] James R Lackner. “Motion sickness: more than nausea and vomiting.” eng. In: *Experimental brain research* 232.8 (2014), pp. 2493–2510. ISSN: 0014-4819.

[40] Joseph J LaViola Jr. “A discussion of cybersickness in virtual environments.” In: *ACM Sigchi Bulletin* 32.1 (2000), pp. 47–56.

[41] Guillaume Lucas, Andras Kemeny, Damien Paillot, and Florent Colombet. “A simulation sickness study on a driving simulator equipped with a vibration platform.” In: *Transportation Research Part F: Traffic Psychology and Behaviour* 68 (2020), pp. 15–22. ISSN: 1369-8478. URL: https://www.sciencedirect.com/science/article/pii/S1369847818307009.

[42] Sarah Malone and Roland Brünken. “Hazard Perception, Presence, and Simulation Sickness—A Comparison of Desktop and Head-Mounted Display for Driving Simulation.” In: *Frontiers in Psychology* 12 (2021), p. 1419. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2021.647723. URL: https://www.frontiersin.org/article/10.3389/fpsyg.2021.647723.

[43] Joe McCormick. *Best Racing/Simulator Games of 2019 + How To Get Into Sim Racing*. May 2019. URL: https://drivetribe.com/p/best-racingsimulator-games-of-2019-H1UIgv22SIuSmsPeXVtLDQ?iid=QJTu0TGSRJOkEvYnEjxvFA.

[44] Sam McEachern. *Top 5 Best Racing Simulator Games*. Mar. 2020. URL: https://www.autoguide.com/top-5-racing-simulator-games.

[45] Merriam-Webster. *Oculomotor Definition*. 2021. URL: https://www.merriam-webster.com/dictionary/oculomotor (visited on 05/19/2021).

[46] Merriam-Webster. *Virtual Reality Definition*. 2021. URL: https://www.merriam-webster.com/dictionary/virtual%5C%20reality (visited on 01/31/2021).

[47] Adrian K.T. Ng, Leith K.Y. Chan, and Henry Y.K. Lau. "A study of cybersickness and sensory conflict theory using a motion-coupled virtual reality system." In: *Displays* 61 (2020), p. 101922. ISSN: 0141-9382. DOI: https://doi.org/10.1016/j.displa.2019.08.004. URL: https://www.sciencedirect.com/science/article/pii/S0141938218300301.

[48] David Nield. "How Oculus Rift works: Everything you need to know about the VR sensation." In: (2016). [Online; accessed may, 2021. URL: https://www.wareable.com/vr/how-oculus-rift-works.

[49] Nathan Nessmith On. *ButtKicker Individual Seat Control System (BKA-130-C, 1 mini-CT) - TheButtKicker.com*. [Online; accessed March, 2021]. 2021. URL: https://thebuttkicker.com/buttkicker-individual-seat-control-system-bka-130-c-1-mini-ct/.

[50] Oxford-English-Dictionary. *Virtual Reality Definition*. 2021. URL: https://www.oed.com/view/Entry/328583?redirectedFrom=virtual+reality#eid (visited on 01/31/2021).

[51] "Maria J. Prohn and Britta Herbig". “"Evaluating the effects of a simulator-based training on knowledge, attitudes and driving profiles of German ambulance drivers".” In: *"Accident Analysis & Prevention"* "138" (2020), "105466". ISSN: "0001-4575". DOI: "https://doi.org/10.1016/j.aap.2020.105466". URL: http://www.sciencedirect.com/science/article/pii/S0001457519308826.

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

[53] Redbull. *Inside look @ Red Bull F1 Simulator w/Mark Webber*. 2010. URL: https://www.youtube.com/watch?v=rE-Fge3gN9w (visited on 02/22/2021).

[54] Grand View Research. *Virtual Reality Market Size, Share & Trends Analysis Report By Technology (Semi & Fully Immersive, Non-immersive), By Device (HMD, GTD), By Component (Hardware, Software), By Application, And Segment Forecasts, 2021 - 2028*. Mar. 2021. URL: https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-market.

[55] Gary E. Riccio and Thomas A. Stoffregen. "An ecological Theory of Motion Sickness and Postural Instability." In: *Ecological Psychology* 3.3 (1991), p. 195. ISSN: 10407413. URL: http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=7403632&site=ehost-live.

[56] Marty Sapp. *Hypnosis, Dissociation, and Absorption : Theories, Assessment, and Treatment*. Vol. Second edition. Charles C Thomas, 2015. ISBN: 9780398081324. URL: http://search.ebscohost.com/login.aspx?direct=true&db=e000xww&AN=967076&site=ehost-live.

[57] Volkan Sevinc and Mehmet Ilker Berkman. "Psychometric evaluation of Simulator Sickness Questionnaire and its variants as a measure of cybersickness in consumer virtual environments." In: *Applied ergonomics* 82 (2020), p. 102958.

[58] SimTools. *What is SimTools motion simulator software?* May 2021. URL: https://simtools.us/about.

[59] Kunos Simulazioni. *Assetto Corsa. Steam.* 2021.

[60] Andrej Somrak, Matevž Pogačnik, and Jože Guna. "Suitability and Comparison of Questionnaires Assessing Virtual Reality-Induced Symptoms and Effects and User Experience in Virtual Environments." In: *Sensors* 21.4 (2021). ISSN: 1424-8220. DOI: 10.3390/s21041185. URL: https://www.mdpi.com/1424-8220/21/4/1185.

[61] Kay M Stanney, Robert S Kennedy, and Julie M Drexler. "Cybersickness is not simulator sickness." In: *Proceedings of the Human Factors and Ergonomics Society ... Annual Meeting* 2 (1997), p. 1138. DOI: 10711813. URL: https://www.proquest.com/scholarly-journals/cybersickness-is-not-simulator-sickness/docview/235470502/se-2?accountid=45259.

[62] Steam. "SteamVR." In: (2021). [Online; accessed May, 2021]. URL: https://store.steampowered.com/steamvr#HowItWorks.

[63] Thomas A. Stoffregen and Gary E. Riccio. "An Ecological Critique of the Sensory Conflict Theory of Motion Sickness." In: *Ecological Psychology* 3.3 (1991), p. 159. ISSN: 10407413. URL: http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=7403630&site=ehost-live.

[64] Ewelina Stollberg and Klaus W Lange. "The effects of video racing games on risk-taking in consideration of the game experience." In: *Federation Internationale de Football Association–FIFA* 15 (2020), pp. 1–15. DOI: 10.1371/journal.pone.0240367. URL: https://www.proquest.com/scholarly-journals/effects-video-racing-games-on-risk-taking/docview/2450183145/se-2?accountid=45259.

[65] SWOV. *Driver training and driving tests.* Tech. rep. Institute for road safety research, The Hauge, NL, Fact sheet, 2019. URL: https://www.swov.nl/en/facts-figures/factsheet/driver-training-and-driving-tests.

[66] SWOV. *Simulators in driver training.* Tech. rep. Institute for road safety research, Leidschendam, NL, Fact sheet, 2010. URL: https://www.swov.nl/en/publication/simulators-driver-training.

[67] Vive Team. *HTC VIVE UNVEILS COMPLETE VIVE COSMOS SERIES.* [Online; accessed april, 2021]. 2020. URL: https://blog.vive.com/us/2020/02/20/htc-vive-unveils-complete-vive-cosmos-series/.

[68] Unity. *Unity Platform.* Mar. 2021. URL: https://unity.com/products/unity-platform.

[69] Marcel Walch, Julian Frommel, Katja Rogers, Felix SchÃ¼ssel, Philipp Hock, David Dobbelstein, and Michael Weber. "Evaluating VR Driving Simulation from a Player Experience Perspective." In: May 2017. DOI: 10.1145/3027063.3053202.

[70] Hannah Walter, Ruixuan Li, Justin Munafo, Christopher Curry, Nicolette Peterson, and Thomas Stoffregen. "APAL coupling study 2019." In: (2019).

[71] SÃ©amas Weech, Sophie Kenny, and Michael Barnett-Cowan. "Presence and Cybersickness in Virtual Reality Are Negatively Related: A Review." In: *Frontiers in Psychology* 10 (2019), p. 158. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2019.00158. URL: https://www.frontiersin.org/article/10.3389/fpsyg.2019.00158.

[72] J. C.F. de Winter, S. de Groot, M. Mulder, P. A. Wieringa, J. Dankelman, and J. A. Mulder. "Relationships between driving simulator performance and driving test results." In: *Ergonomics* 52.2 (2009). PMID: 18972239, pp. 137–153. DOI: 10.1080/00140130802277521. eprint: https://doi.org/10.1080/00140130802277521. URL: https://doi.org/10.1080/00140130802277521.

[73] Bob G. Witmer and Michael J. Singer. "Measuring Presence in Virtual Environments: A Presence Questionnaire." In: *PRESENCE: Teleoperators & Virtual Environments* 7.3 (1998), pp. 225–240. ISSN: 10547460. URL: http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=714052&site=ehost-live.

[74] Rachael A. Wynne, Vanessa Beanland, and Paul M. Salmon. "Systematic review of driving simulator validation studies." In: *Safety Science* 117 (2019), pp. 138–151. URL: https://www.sciencedirect.com/science/article/pii/S0925753518320459.

[75] Caglar Yildirim. "Dont make me sick: investigating the incidence of cybersickness in commercial virtual reality headsets." In: *Virtual Reality* 24.2 (2020), 231â€"239. DOI: https://doi.org/10.1007/s10055-019-00401-0. URL: http://link.springer.com/10.1007/s10055-019-00401-0.

[76] S. D. Young, B. D. Adelstein, and S. R. Ellis. "Demand Characteristics in Assessing Motion Sickness in a Virtual Environment: Or Does Taking a Motion Sickness Questionnaire Make You Sick?" In: *IEEE Transactions on Visualization and Computer Graphics* 13.3 (2007), pp. 422–428. DOI: 10.1109/TVCG.2007.1029.

Appendix A

Interview

1. Participant

2. Age

3. Gender

- Woman
- Man
- Non-binary
- Prefer not to say

4. Why did you choose to participate?

5. Drivers License (car)

- yes
- No

6. Experience with VR?

- None
- Some
- A lot

7. Experience with racing games?

- None
- Some
- A lot

8. Prone to sickness?

	Never	Sometimes	Often	Always
Carsick	○	○	○	○
Seasick	○	○	○	○
Amusement rides	○	○	○	○
Air-planes	○	○	○	○

9. Motor racing?

Figure A.1: Pre interview question for scenario 0

1. Participant

2. What moments generated disconfort if any?

3. Was the experience realistic?

Not at all ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ Very

4. Was there anything missing?

5. Could simulators be used to train driving/racing?

Figure A.2: Post interview question for scenario 0

1. Participant
2. Realisme

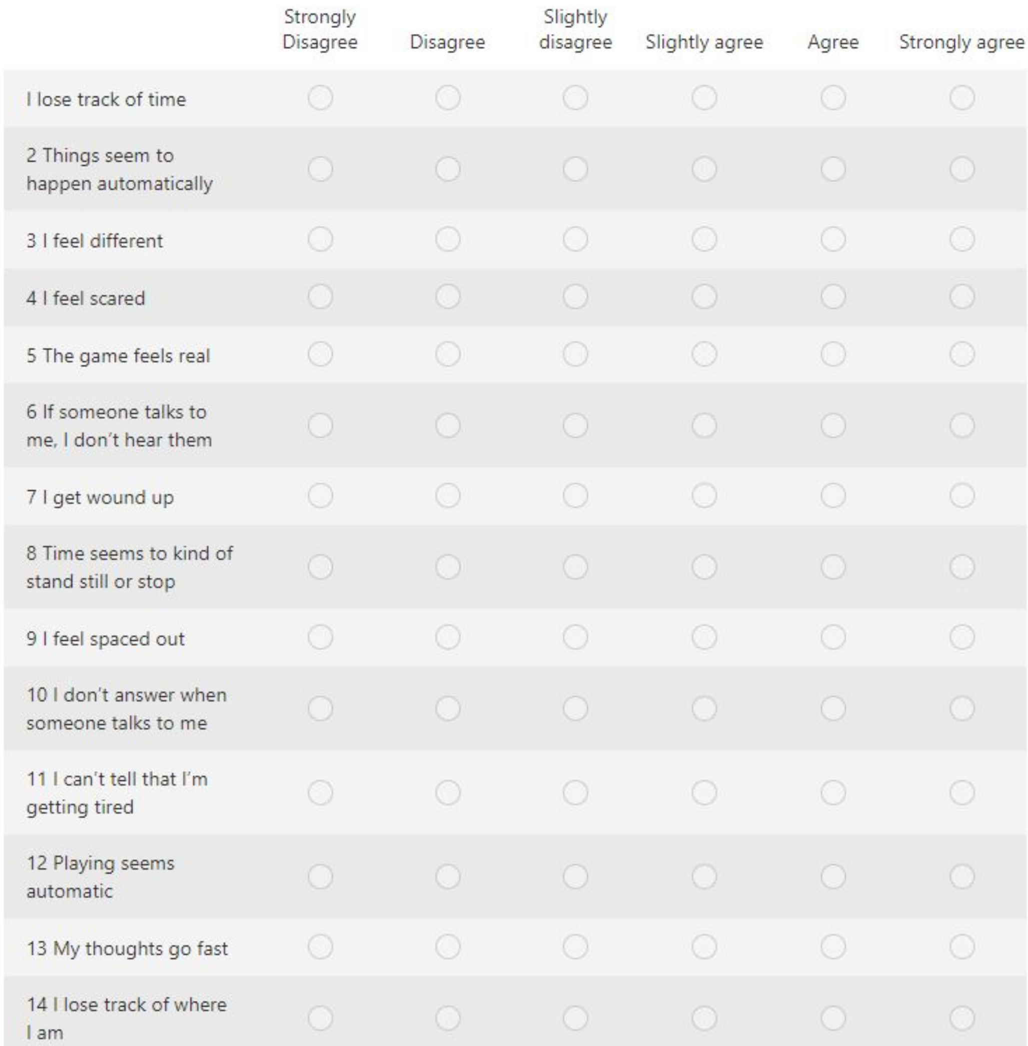
1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

3. Hva tenker du om bevegelsene?

Figure A.3: Post interview question scenario 1 and 2

	Not at all	Slight	Moderate	Severe
General discomfort	○	○	○	○
Fatigue	○	○	○	○
Headache	○	○	○	○
Eyestrain	○	○	○	○
Difficulty focusing	○	○	○	○
Increased salvation	○	○	○	○
Sweating	○	○	○	○
Nausea	○	○	○	○
Difficulty concentration	○	○	○	○
Fullness of head	○	○	○	○
Blurred vision	○	○	○	○
Dizzy (eyes open)	○	○	○	○
Dizzy (eyes closed)	○	○	○	○
Vertigo	○	○	○	○
Stomach awareness	○	○	○	○
Burping	○	○	○	○

Figure A.4: SSQ interview question for every scenario



	Strongly Disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
I lose track of time						
2 Things seem to happen automatically						
3 I feel different						
4 I feel scared						
5 The game feels real						
6 If someone talks to me, I don't hear them						
7 I get wound up						
8 Time seems to kind of stand still or stop						
9 I feel spaced out						
10 I don't answer when someone talks to me						
11 I can't tell that I'm getting tired						
12 Playing seems automatic						
13 My thoughts go fast						
14 I lose track of where I am						

Figure A.5: GEQ interview question for every scenario part 1

	Strongly Disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
15 I play without thinking about how to play						
16 Playing makes me feel calm						
17 I play longer than I meant to						
18 I really get into the game						
19 I feel like I just can't stop playing						

Figure A.6: GEQ interview question for every scenario part 2

Appendix B

Datasheet: Results

B.1 SSQ

	Mean			Median			Standard deviation		
	Total	Men	Woman	Total	Men	Woman	Total	Men	Woman
Nausea 0	19,08	18,76	20,14	9,54	14,31	9,54	24,63	23,95	26,01
Nausea 1	27,40	27,67	20,14	19,08	19,08	9,54	29,08	28,51	30,32
Nausea 2	22,26	25,12	16,96	28,62	28,62	9,54	21,85	22,44	15,43
Oculomotor 0	13,02	12,63	12,63	7,58	11,37	7,58	20,16	19,86	22,31
Oculomotor 1	20,99	23,75	11,79	15,16	15,16	7,58	25,37	26,70	17,91
Oculomotor 2	13,99	14,4	16,00	7,58	7,58	15,16	15,69	15,85	14,49
Disorientation 0	42,47	38,51	52,59	27,84	27,84	27,84	42,87	41,97	44,88
Disorientation 1	48,90	52,43	34,03	41,76	41,76	13,92	46,85	46,67	43,58
Disorientation 2	32,37	35,04	28,12	27,84	27,84	25,56	33,27	33,72	30,64
Total Score 0	25,13	23,69	28,26	14,96	14,96	14,96	27,25	27,14	27,94
Total Score 1	34,24	36,65	22,86	29,92	33,66	11,22	32,81	33,17	30,81
Total Score 2	23,69	26,06	20,36	18,70	20,57	14,96	23,08	23,79	18,16

Figure B.1: Overall list SSQ score, all the 39 participant, men and woman

	Mode			Max		
	All	Men	Woman	All	Men	Woman
Nausea 0	0,00	0	0,00	104,94	104,94	76,32
Nausea 1	0,00	0	0,00	95,40	95,4	76,32
Nausea 2	0,00	0	0,00	76,32	76,32	38,16
Oculomotor 0	0,00	0	0,00	60,64	60,64	53,06
Oculomotor 1	0,00	0	0,00	90,96	90,96	60,64
Oculomotor 2	0,00	0	0,00	53,06	53,06	45,48
Disorientation 0	0,00	0	83,52	153,12	139,2	153,12
Disorientation 1	0,00	0	0,00	167,04	167,04	111,36
Disorientation 2	0,00	0	0,00	111,36	111,36	102,25
Total Score 0	14,96	14,96	0,00	86,02	86,02	71,06
Total Score 1	0,00	0	0,00	127,16	127,16	89,76
Total Score 2	0,00	0	0,00	86,02	86,02	52,36

Figure B.2: Overall list SSQ score, all the 39 participant, men and woman

	Mean			Median			Standard deviation		
	Excluding 18 first particpents	Only the 18 first particpents	Finish senario 2 before 1	Excluding 18 first particpents	18 first particpent	Finish senario 2 before 1	18 first particpents	Only the 18 first particpent	Finish senario 2 before 1
Nausea 0	19,08	19,08	23,85	9,54	19,08	14,31	26,66	22,03	27,40
Nausea 1	20,90	34,98	21,47	9,54	19,08	23,85	23,30	33,05	7,91
Nausea 2	22,71	21,73	26,24	28,62	19,08	28,62	22,71	20,81	4,13
Oculomotor 0	13,36	12,63	20,85	7,58	15,16	15,16	21,55	18,39	20,32
Oculomotor 1	16,24	26,53	28,43	7,58	15,16	30,32	18,90	30,35	8,26
Oculomotor 2	15,88	11,79	17,06	15,16	7,58	18,95	17,49	12,94	6,29
Disorientation	37,78	47,95	52,20	13,92	27,84	48,72	44,47	40,24	42,19
Disorientation	37,78	61,87	62,64	27,84	69,6	62,64	36,49	53,76	37,48
Disorientation	37,58	26,29	55,68	27,84	27,84	55,68	38,98	23,61	13,92
Total Score 0	24,58	25,76	33,66	11,22	18,7	33,66	29,69	24,07	28,61
Total Score 1	26,36	43,43	39,27	18,70	37,4	37,40	26,08	37,17	13,61
Total Score 2	25,65	21,4	33,66	18,70	14,96	35,53	26,02	18,82	7,00

Figure B.3: Overall list SSQ score for special cases

	Mode			Max		
	Excluding 18 first particpents	Only the 18 first particpent	Finish senario 2 before 1	Excluding 18 first particpents	18 first particpent	Finish senario 2 before 1
Nausea 0	0,00	0	0,00	104,94	76,32	66,78
Nausea 1	0,00	0	28,62	76,32	95,4	28,62
Nausea 2	0,00	0	28,62	76,32	57,24	28,62
Oculomotor 0	0,00	0	Not viable	53,06	60,64	53,06
Oculomotor 1	7,58	0	30,32	60,64	90,96	37,90
Oculomotor 2	0,00	0	22,74	53,06	37,9	22,74
Disorientation	0,00	27,84	Not viable	153,12	139,2	111,36
Disorientation	0,00	111,36	Not viable	111,36	167,04	111,36
Disorientation	0,00	13,92	69,60	111,36	83,52	69,60
Total Score 0	0,00	14,96	Not viable	86,02	82,28	67,32
Total Score 1	0,00	0	Not viable	86,02	127,16	59,84
Total Score 2	0,00	0	Not viable	86,02	56,1	41,14

Figure B.4: Overall list SSQ score for special cases

B.2 GEQ

	Scenario 0	
Participant	GEQ	SSQ
12	82	22
13	59	37
15	46	15
16	50	82
17	67	22
18	65	15
19	57	0
21	59	15
22	70	0
26	84	7
29	82	7
28	58	-4
30	57	86
31	69	-19
33	65	11
37	65	30
34	60	56
38	74	-4
35	83	11
41	73	11
49	68	37
53	66	64
54	71	71
55	62	7

t-Test: Paired Two Sample for Means

	SSQ	*GEQ*
Mean	24.31	66.33333333
Variance	805.1992	101.1014493
Observatio	24	24
Pearson Co	-0.31915	
Hypothesiz	0	
df	23	
t Stat	-6.24018	
P(T<=t) one	1.14E-06	
t Critical or	1.713872	
P(T<=t) two	2.29E-06	
t Critical tw	2.068658	

	Scenario 1	
Participant	GEQ	SSQ
12	65	56
13	58	0
15	41	52
16	47	127
17	71	15
18	69	7
19	62	0
21	72	34
22	73	41
26	85	75
29	68	-4
28	69	7
30	61	56
31	75	-11
33	76	0
37	55	19
34	85	22
38	74	0
35	86	11
41	64	34
49	67	45

t-Test: Paired Two Sample for Means

	SSQ	*GEQ*
Mean	27.27083	68.33333333
Variance	967.5517	120.9275362
Observatio	24	24
Pearson Co	-0.36763	
Hypothesiz	0	
df	23	
t Stat	-5.49543	
P(T<=t) one	6.88E-06	
t Critical or	1.713872	
P(T<=t) two	1.38E-05	
t Critical tw	2.068658	

53	79	11
54	67	19
55	71	37

	Scenario 2	
Participant	GEQ	SSQ
12	75	11
13	72	22
15	62	49
16	59	56
17	69	0
18	78	15
19	58	0
21	72	7
22	76	37
26	67	82
29	58	0
28	65	0
30	70	60
31	77	0
33	73	19
37	64	0
34	83	22
38	65	0
35	80	26
41	75	34
49	72	34
53	59	52
54	68	15
55	58	0

t-Test: Paired Two Sample for Means

	SSQ	*GEQ*
Mean	22.59583	68.95833333
Variance	551.5726	56.5634058
Observatio	24	24
Pearson Co	0.0028	
Hypothesiz	0	
df	23	
t Stat	-9.21776	
P(T<=t) one	1.74E-09	
t Critical or	1.713872	
P(T<=t) twc	3.47E-09	
t Critical tw	2.068658	

Scenario 0	*SSQ*	*Presence*
Mean	20.0464	16.16
Variance	661.94	15.39
Observations	25	25
Pearson Correlation	-0.41909	
Hypothesized Mean Difference	0	
df	24	
t Stat	0.70398	
P(T<=t) one-tail	0.24411	
t Critical one-tail	1.71088	
P(T<=t) two-tail	0.48822	
t Critical two-tail	2.0639	

Scenario 1	*SSQ*	*Presence*
Mean	33.486	16.23255814
Variance	1150.95	15.2303433
Observations	43	43
Pearson Correlation	-0.45367	
Hypothesized Mean Difference	0	
df	42	
t Stat	3.15456	
P(T<=t) one-tail	0.00148	
t Critical one-tail	1.68195	
P(T<=t) two-tail	0.00297	
t Critical two-tail	2.01808	

Scenario 2	*SSQ*	*Presence*
Mean	23.035	17.04545455
Variance	530.191	12.04439746
Observations	44	44
Pearson Correlation	-0.20606	
Hypothesized Mean Difference	0	
df	43	
t Stat	1.65662	
P(T<=t) one-tail	0.05244	
t Critical one-tail	1.68107	
P(T<=t) two-tail	0.10488	
t Critical two-tail	2.01669	

Figure B.5: Dependent t-test results for the three scenarios done in excel

Participants finnish all scenarios	Scenario 0	Scenario 1	Scenario 2
SSQ			
SSQ results			
AVG	25.7	33.5	24.1
SD	25.6	33.5	22.7
GEQ Answers			
Absorption			
I feel scared	37	41	44
I lose track of where I am	78	74	76
I feel different	84	82	78
Time seems to kind of stand still or stop	84	83	63
I feel spaced out	74	73	82
Average score	71.4	70.6	68.6
SD	17.6	15.3	13.9
Flow			
I don't answer when someone talks to me	53	55	55
I can't tell if I'm getting tired	79	83	85
If someone talks to me, I don’t hear them	60	58	63
I feel like I just cant stop playing	76	88	93
The game feels real	97	106	105
I get wound up	120	117	123
Playing seems automatic	92	104	97
I play without thinking about how to play	88	87	79
Playing makes me feel calm	60	68	78
AVG	83.1	85.1	86.4
SD	22.5	20.4	19.7
Presence			
Things seem to happen automatically	87	100	105
My thoughts go fast	101	100	102
I play longer than I meant to	97	98	109
I lose track of time	109	101	98
AVG	98.5	99.75	103.5
SD	7.9	1.1	4.0
Immersion			
I really get into the game	116	122	120
AVG	166	213	218
SD	1.105541597	0.862006703	0.912870929
Total Average			
Average	83.79	86.32	87.11
Standard deviation	20.78	20.76	21.03

Figure B.6: Uses only the results from the participants that finished all three scenarios. The answer for each question is summed up and divided into three areas of measurement. The SSQ score for the participants is also included.

Appendix C

Consent forms

C.1 English version for Align Racing drivers

Do you want to participate in the research project "VR racing simulering"?

This is a question for you to participate in a research project where the purpose is to find out if movement reduces "cybersickness." This letter gives you information about the project's goals and what participation will mean for you.

Purpose

The purpose of the project is to find out if you can reduce "cybersickness," which is a prevalent form of motion sickness that occurs in VR (virtual reality). This research project will take place over six months and is part of a master's thesis at the University of Agder.

Who is responsible for the research project?

The University of Agder is responsible for the project.

Why are you asked to participate?

You have been selected to participate in this research project because you are a driver for Align Racing and have an expertise of racing cars to a higher degree than the average participant.

What does it mean for you to participate

If you choose to participate in the project, you will participate in a pre-interview and then use a simulator, followed by completing a questionnaire. You will be asked to visit us 3 times, this whole process will take you approx. 60-70 minutes. The questionnaire contains questions about the degree to which you felt uncomfortable or nauseous. Your answers from the questionnaire will be registered electronically. Audio recordings, video recordings, and notes from the interview and the simulation are made. It is not mandatory to participate in video recordings and audio recordings by not ticking the hatch in the consent form under "Additional consent" for video recordings and audio recordings if you are not interested in being filmed or recorded.

Audio and video will be taken from you during the simulation, where it is used to observe you and examine if there was anything the test conductor missed during the testing. Simulator Sickness Questionnaire (SSQ) is the survey we will use as our questionnaire. It is made by Kennedy et al. (1993) and is popular for testing Motion sickness of Cybersickness. SSQ is a modified version of the Pensacola Motion Sickness Questionnaire (MSQ), the standard questionnaire for motion sickness, where SSQ is a customized questionnaire for the simulator.

It is voluntary to participate

It is voluntary to participate in the project. If you choose to participate, you can withdraw your consent at any time without giving any reason. All your personal information will be deleted. It will not have any negative consequences if you do not want to participate or later choose to withdraw.

Your privacy - how we store and use your information

We will use the information about you for the purposes we have described in this article. We treat the information confidentially and in accordance with the privacy regulations. Only members of the project group will have access to raw data, and no information will be published in such a way that an individual can be identified. Your name and signature will not be used for anything other than a statement of consent. Microsoft forms will be used as a data processor of the data you provide in our questionnaire. We have your permission to use your given data. If you feel that something we have published can be identified, you contact Andreas Langåker by sending an email to andreasla@uia.no or Stian Ngo by sending an email to stian.ngo@uia.no to have it changed or removed.

What happens to your information when we end the research project?

The information is anonymized when the project is completed / the assignment is approved, which according to the plan is 10.06.2021 when digital raw data will be deleted and written data shredded.

Your rights

As long as you can be identified in the data material, you have the right to:

- access to which personal information is registered about you, and to receive a copy of the information,
- to have personal information about you corrected,
- to have personal information about you deleted, and
- to send a complaint to the Norwegian Data Protection Authority about the processing of your personal data.

What entitles us to process personal information about you?

We process information about you based on your consent.

On behalf of the University of Agder, NSD - Norwegian Center for Research Data AS has assessed that the processing of personal data in this project is in accordance with the privacy regulations.

What entitles us to process personal information about you?

We process information about you based on your consent.

On behalf of the University of Agder, NSD - Norwegian Center for Research Data AS has assessed that the processing of personal data in this project is in accordance with the privacy regulations.

Where can I find out more?

If you have questions about the study or want to exercise your rights, contact the University of Agder by contacting:

- Andreas Langåker: andreasla@uia.no
- Stian Ngo stian.ngo@uia.no

Supervisor:

- Morgan Konnestad morgan.konnestad@uia.no
- Ghislain Maurice Norbert Isabwe maurice.isabwe@uia.no

Our privacy representative:

- Ina Danielsen ina.danielsen@uia.no

If you have questions related to NSD's assessment of the project, you can contact:

NSD - Norwegian Center for Research Data AS by email (personverntjenester@nsd.no) or by phone: 55 58 21 17.

With best regards

Andreas Langåker og Stian Ngo

(Morgan Konnestad,Ghislain Maurice Norbert Isabwe)

Consent Form

Content

The signee hereby referred to as the participant will acknowledge and understand the content of this document by signing this document. They thereby agree to participate in a voluntary manner in the project: “VR racing simulering” at the University of Agder. They understand that they can at any moment under participation raise concerns or areas of discomfort with member(s) of the research team. Participants must also understand that they have the right at any moment to withdraw from this participation and the data collected on them is destroyed immediately, once a member of the research team has been given a written notice and acknowledged the wish to withdraw.

Terms:

The participant consent to the following terms when signing this document:

- The participant will allow themselves to be observed.
- The participant allows for their screen to be recorded on a device provided by the research team.
- The data collected during their session can be published, but the identity will be kept anonymous.
- The research group is permitted to save and hold raw test data until no later than the 10th of June 2021 before being destroyed. The participant must be aware that no raw data will be stored in a cloud service of any kind.
- No raw data will be shared outside the research group of any kind.

Additional consent:

☐ I am aware and allow that excerpts from the interview may be included in publications to come from this research. Quotations will be kept anonymous.

☐ I give permission to be recorded using **video** recording equipment.

☐ I give permission to be recorded using **audio** recording equipment.

☐ I give permission to ask me questions about my health when it comes to different types of motion sickness.

--------------------------------------- --------------------------------------

Participant Signature Date and Location

Contact information:

Andreas Langåker: andreasla@uia.no
Stian Ngo stian.ngo@uia.no