Thomas André Skaaheim

Towards a driving license in VR

Assisting young drivers learning safe driving in Norway using VR technology

Master's thesis in Master of Science in Informatics - Interaction Design, Game- and Learning Technology
Supervisor: Simon McCallum
Co-supervisor: Ekaterina Prasolova-Førland
June 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
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NTNU
Kunnskap for en bedre verden

Abstract

A driving simulator solution using the XTAL VR headset, which was provided by Way AS traffic school, were developed and tested, to investigate if it can be used to pass the night driving course in Norway. To achieve this, a supplementary survey study was conducted to compare the learning outcome between a simulator-based teaching approach, and a traditional teaching approach for the mandatory night driving course. In addition, a motion system were implemented to see if this reduced the risk of simulator sickness. The results showed how the solution can be used as a learning tool, that the VR course were non-inferior to the traditional approach, in terms of learning outcome, and that this motion system reduced the risk of simulator sickness.

Summary

The research project was conducted in cooperation with Way AS traffic school in Trondheim, Norway. This project was motivated by recent interest in virtual reality (VR) technology, the legal challenges in using simulators to pass the mandatory activities in the Norwegian driving training, and based on a request from Way AS. A driving simulator using VR technology was developed and tested, primarily, to see whether the mandatory night driving training can be passed with the use of VR technology of research quality, when applied in a driving simulator. One of the main requirements was that it had to provide a learning outcome, which was non-inferior to a traditional teaching approach. The secondary objective was to investigate how a motion system influenced the risk of simulator sickness, with the goal to verify its viability as a preventative measure for VR driving simulators.

To answer the primary objective, it was decided to measure the learning tools' effectiveness through the learning outcome acquired from each course. The learning outcome was based on the change of traffic awareness, subjective- and objective assessment before and after a night driving course was conducted in VR, and by traditional means.

To achieve this, a supplementary survey study was chosen to support related works with more test samples, and was the primarily source to collect quantitative data for a statistical analysis to find common patterns. Secondarily, an extensive collection of past research was gathered to represent what we know of driving simulators today. This included basic theory about VR technology and driving simulators in general, possible challenges and benefits, and how they were used to support learning. The results from the simulator sickness risk assessment was compared to related works and theories, to address the motion system as a preventative measure against simulator sickness.

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This master thesis was possible thanks to NTNU for providing me adequate prerequisites. Also, I would like to thank my advisers, Simon McCallum and Eketerina Prasolova-Førland, for their support and guidance when writing this thesis.

I would like to thank Way AS traffic school for providing their resources, insights, knowledge, and contribution to the research. In addition, I would also make a special thanks to CEO Ståle Svenning, and CTO Thor Henning Amdahl for their cooperation, and for reaching out to me.

This has been an educational, instructive research journey thanks to their support and assistance.

Figure 1: Logo Way AS

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Code Listings

Acronyms

2D Two Dimensional. 10

CAVE Cave Automatic Virtual Environment. xiii, xiv, 3, 18, 27–29, 34, 35, 71, 72

DOF Degree of Freedom. 42

DTS Driving Training Simulator. 67

FOV Field of View. 7, 10, 12, 21, 68

FPS Frames Per Second. 44, 70, 74

GDE Goals for Driver Education. 25

HCI Human Computer Interaction. 2

HMD Head Mounted Display. 7, 22, 42, 68, 77, 83

HMI Human Machine Interaction. 21

LTS Long Term Support. 44

MIT Massachusetts Institute of Technology. 70

NPRA Norwegian Public Road Administration. 1, 16, 18, 19, 25, 27, 67, 68

NTNU Norwegian University of Science and Technology. 2, 18, 21, 25, 33

PC Personal Computer. 9, 10

RCT Randomized Controlled Trials. 31

RQ Research Question. 2–4

SS Simulator Sickness. xv, 2, 4, 7, 13, 22, 32, 33, 37, 41, 46, 64, 70–73, 75, 82, 83

UDP User Datagram Protocol. 42

VA Visual Assets. 22, 72, 82

VR Virtual Reality. xiii–xvi, 1–5, 7, 10, 12, 16, 18, 19, 21, 22, 31–34, 39, 41, 42, 45–49, 51–54, 56–59, 61–65, 67–77, 81–83, 141, 143, 144, 146–148, 150

Chapter 1

Introduction

1.1 Background

The use of driving simulators in Norway is both limited and restricted, compared to other countries (Sætren, Lindheim *et al.* 2019, p. 1669). These are mainly due to legal and technological limitations. However, "[..By eliminating these limitations, the full potential of VR driving simulator could be effectively applied to generate an efficient and near-realistic driving experience of hazardous driving situations without endangering the life of the driver..]" (Ihemedu-Steinke, Sirim *et al.* 2015, p. 499).

Furthermore, driving simulators are steadily becoming more relevant in research and in driving training applications for research organisations (Moe 2006) (Moe 2007), universities (Engen 2008) (Sætren, Lindheim *et al.* 2019), driving schools (Amdahl 2020), and the Norwegian Public Roads Administration (NPRA) (K. Robertsen *et al.* 2020). This shows the motivation to utilise driving simulators, and VR technology as learning tools, and the interest to apply these technologies in the Norwegian driving education.

In the year 2020, only 5-10 out of 1033 driving schools in Norway offer simulator training for driving license category B, which includes vehicles with legal total weight up to 3500 kg. Due to the legal challenges and strict requirements for conducting mandatory driving training, these simulators are mainly used for learning basic introductory elements of handling and manoeuvring a car (Sætren, Pedersen *et al.* 2018, p. 2046).

However, with the final goal to utilise simulators to pass mandatory activities in the Norwegian driving education, Way AS traffic school (Way 2020), henceforth referenced as Way, aimed to offer a simulator-based night driving course with their high fidelity simulators. "[..Advancements in computer science have steadily improved the performance of driving simulators, making them cheaper and more widely available.]" (Engen 2008, p. 126). However, the study (SWOV 2020,

p. 3-4) suggested that high fidelity simulators are too expensive to be used for driving training. In cooperation with Way, I was assigned the task to develop and test a simulator solution, to see whether a cheaper solution, compared to their high fidelity simulators, can be used to conduct the night driving training (Amdahl 2020). In addition, I hope to supplement related research, such as the recent comparative study (Sætren, Lindheim *et al.* 2019) with more test sample.

The thesis is within the field of interaction design, game- and learning technology at NTNU in Trondheim, Norway, because it addresses a VR driving simulator in the field's three main aspects: 1) the human-computer interaction (HCI) between the virtual- and the real world in terms of learning, 2) how the real world is imitated through gamification, and 3) the effectiveness of virtual reality as a learning technology. The field of interaction design has the objective to provide a way for a system to communicate its functions to its user. In other terms, make it usable through an interface, which is in this case, is a VR driving simulator.

1.2 Objective of the thesis

The objective of this thesis is to examine how VR technology can be used to pass the night driving course, which is one of the mandatory driving activities in the Norwegian driving education. The problem I will examine is:

> *How can the practical, mandatory part of the night driving course be executed, using VR technology, to give a learning outcome that is non-inferior to the results from the traditional approach?*

The topics learned in the night driving course are "[..causes and effects in connection with accidents in the dark, risk assessment, appropriate behaviour and use of lights when you drive, park, and how to make emergency stops in the dark.]" (Norwegian Public Roads Administration 2017). The learning outcome depends on the students' self-evaluation, and the gained experience after completing the course. To assess the main problem, I want to investigate three research questions (**RQ**), which represent the different parts of the problem. **RQ1** examines the potential of utilising a VR simulator as a driving education tool. This includes what we know about simulators, existing simulator applications, potential benefits and challenges, and a learning outcome comparison between different teaching approaches. **RQ2** examines how a motion system influences the risk of simulator sickness (SS), when applied in a VR driving simulator. I hope to answer this through a comparison between existing documents and theories, and the test results. Lastly, **RQ3** examines how the night driving training conducted with a VR simulator provides a learning outcome non-inferior to the traditional approach. These are summarised as following:

> **RQ1**: How can a VR driving simulator be used as a learning tool?
>
> **RQ2**: How can a motion system influence the probability of simulator sickness, when applied in a VR simulator?
>
> **RQ3**: How can a VR simulator be non-inferior to the traditional approach in terms of learning outcome, when used to replace the night driving course?

These RQs will, hopefully, be answered through a survey study, which is supported by comprehensive literature studies of a simulator as an education- and a research tool. It was decided to evaluate the VR technology's effectiveness as a learning tool using the XTAL VR headset. I hoped that this technology would offer a visual quality non-inferior to high fidelity simulators, due to its increasingly immersive factor and research quality. Combined with a motion system, will this solution rival the performance of high fidelity simulators, and bring the driving simulator solution closer to the on-road driving?

The VR simulator was the main focus, but other simulator types were introduced as well, because a simulator using VR technology would naturally inherit a simulator's potential benefits and challenges in general. The results from the test case were analysed and compared, to evaluate whether the solution was viable to conduct the mandatory driving training. I hoped to learn more about the VR driving simulator's potential, when included as a part of the mandatory driving training in the Norwegian driving education.

1.3 Business cooperation with Way AS

This document is written in cooperation with Way. Way is one of few traffic schools in Norway who focus on the use of simulators for driving training. Way was established in June 2015, and the business has started its own simulator centre in Trondheim with 18 employees. They were interested in utilising simulators as a part of the driving training, because they saw the simulators' potential as a learning tool.

Way's CAVE simulators were able to cover all of the mandatory driving training technology- and pedagogically wise. When utilising a real car, the students were able to familiarise themselves with the car's functions. Although, none of the mandatory driving training can be passed using these simulators by jurisdiction, there is an increased interest to reform the regulations to allow the use of simulators to pass mandatory courses in the Norwegian traffic education (K. Robertsen *et* *al.* 2020). The end goal is to use the simulators to increase the students' skill as quickly as possible, and to allow students to pass the mandatory training with the use of these simulators (Amdahl 2020).

Additionally, Way is interested to verify existing finds in research conducted at Nord university, such as the comparative study (Sætren, Lindheim *et al.* 2019). An experimental VR simulator setup was developed to test a more profitable solution compared to Way's existing simulators. Question is, will this solution be non-inferior compared to traditional methods, in terms of learning outcome for the night driving course? This was covered by RQ1 and RQ3. Moreover, one of the challenges when driving in simulators that use VR technology, is the risk of SS. Therefore, Way wants to investigate how a motion system influences the risk of SS when using VR technology, which was covered by RQ2.

1.4 Limitations of the research

The majority of candidates for the night driving course in Norway were minors. From personal experience, it was harder to motivate minors to participate in the research project, due to their lack of independence or prerequisites. The use of a e-mail as a communication channel was difficult to implement, because the minors were unfamiliar with this. See Section 5.4.2 for more details on this.

Simulators are defined as an *imitation* of the real world, see Section 2.2.1 for more explanation. The real world consists of almost endless permutations and variances, which are, now, impossible to imitate perfectly. If we ever were able to, it would contradict the definition of a simulator, as it would no longer be an imitation. However, the goal is not to make the simulation experience completely real, as the simulator is never being used on a real road. On the other hand, it can be used to trick the brain to the point where the transfer of learning is optimal. This impacts the accuracy of the simulation experience, which results in a different outcome compared to what the case would be in a real life test.

1.5 Scope of the thesis

The focus of this thesis was to develop and test a VR driving simulator's feasibility as a learning tool, and specifically investigate whether the learning outcome gained by this was non-inferior to a traditional learning approach for the night driving course.

There are strengths and weaknesses for all data recording methods. There is a need to evaluate whether a VR simulator of research quality, passes the minimum requirements to be a learning tool in the Norwegian driving education. This thesis contains an extensive collection of related studies as a means of comparison. It was decided to use a supplementary survey study, consisting of questionnaires, to collect data to support, and verify existing studies with the test sample.

My thesis contains the following chapters, which are new and based on my research:

> Chapter 2.2.2 "Example 2 - Mid-level simulator at Way" - This chapter contains a brief description of the VR application at Way, which was used to conduct this research.
>
> Chapter 2.5.4 "How driving simulators are utilised at Way" - This chapter describes how Way has applied driving simulators as a learning tool to conduct driving training in an alternative way.
>
> Chapter 3.3 "Testing tools" - This chapter contains the specs of the VR application that was developed to conduct this research.
>
> Chapter 3 "Results" - In this chapter, research was conducted to determine whether the learning outcome from completing the night driving course in a VR simulator was non-inferior to the traditional learning approach.
>
> Chapter 5.4.2 "Retrospect" - The chapter describes my retrospect, which includes what I would do differently, if I were to write this thesis again.
>
> Chapter 5.4.3 "COVID-19" - This chapter describes how the research project was influenced by the global pandemic, COVID-19.
>
> Chapter 5.5 "An interface inspection of Way's VR simulator" - In this chapter, I conducted an interface inspection of the simulator solution to support Way in their future research, and to demonstrate my skills as an interaction designer.

The rest of the chapters are primarily a summary of existing knowledge based on a literature review, and conversation with colleagues and other researchers.

1.6 Outline of the thesis

Chapter 1 introduces the paper's research question and basis. Chapter 2 covers what we already know about driving simulators when applied in research and education, as well as three application examples in Norway. This chapter also includes related work and theories, simulators' possible advantages and disadvantages, and basic theory about driving simulators and VR technology in general.

Chapter 3 explains the methodology. The results from the test cases were presented in Chapter 4, and discussed in Chapter 5. In addition, the chapter includes methodological implications, an interface inspection of the simulator solution, and retrospect. Finally, the conclusion can be found in Chapter 6.

Chapter 2

Background

2.1 VR technology

The interest to include VR technology in driving simulators, has steadily increased in research. Studies related to feasibility (K. Robertsen *et al.* 2020) (Meisam T. *et al.* 2017), evaluation (Ihemedu-Steinke, Sirim *et al.* 2015), validation (Engen 2008), and SS (Park *et al.* 2020) (Ihemedu-Steinke, Rangelova *et al.* 2017) have been conducted to examine the potential benefits and flaws for a VR simulator application with promising results.

VR technology has previously been described as an addition to a driving simulator, but what exactly is VR? VR stands for Virtual Reality and was often experienced through a head-mounted display (HMD). The HMD lets the user control the camera view inside a virtual world with their head's rotation and position. This way, make the experience in the virtual world more immersive. In addition, the XTAL headset guarantees a 180° FOV in every direction, which gives the user a 360° of freedom. Finally, the headset offers virtual hands through hand-tracking. Figure 2.2 shows experimental hands that were used in the test case to improve the imitation, thus, make the experience more immersive.

2.2 Driving simulators

2.2.1 Overview

A simulator has the purpose to "[.. imitate the operation of a real-world process or system over time.]", suggested by (Banks *et al.* 2009, p. 1). In other words, a simulator is used to create models, which mimics parts of the real world. As the name suggested, a *driving* simulation imitates a driving environment, often from a driver's perspective. A recent study (Research 2020) suggested that a "[.. simulator is a machine designed to provide a realistic imitation of the controls and operation of a vehicle, aircraft, or other complex system, used for training purposes.]" In other terms, a driving simulator is a collection of hardware- and

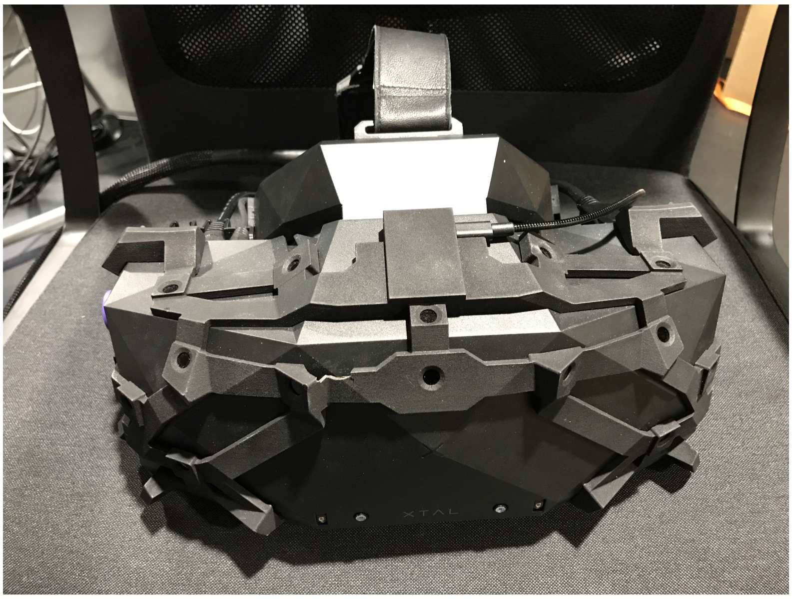

Figure 2.1: The XTAL VR headset by VRgineers.

Figure 2.2: An example of virtual hands made possible with hand-tracking technology. Note, the quality of these are experimental as a demonstration.

software systems that forms a virtual environment to resemble the real world.

There exist different ways to build a driving simulator, which makes it difficult to draw a concrete line between different setups. However, (Engen 2008, p. 9-11), which used (Kaptein *et al.* 1996) as reference, suggested that driving simulators can be divided into three simulator levels, based on their available utilities and features. It was decided to use this categorisation in this thesis as well, because its level hierarchy fits the different simulator setup costs, suggested by the study (K. Robertsen *et al.* 2020). The levels are described briefly as following, with corresponding costs that were suggested by the study (K. Robertsen *et al.* 2020, p. 30-31):

- **Low level driving simulator** - the simulation is run by a PC that has the required hardware and software to run the simulation without performance issues. The simulation has no motion system, and none or few extra utilities. The cost varies between 15.000-40.000 NOK.

- **Mid level driving simulator** – uses intermediate imaging techniques, possibly a simple motion base, and provide utilities to some extent. The budget for these simulators varies from 15.000 NOK to hundreds of thousands of NOK.

- **High level driving simulator** – this is the most advanced form for a driving simulator. The simulator includes advanced imaging techniques, a realistic car, and typically provides close to a 360° panorama view, and an extensive motion system. There is no limit to the amount of utilities, thus, the expenses are only limited to the resources available.

2.2.2 Applications

Both low level (Ihemedu-Steinke, Rangelova *et al.* 2017) and high level (Hirsch and Bellavance 2016a) simulators were used to conduct past research, see Section 2.3 for more details. A quick "driving simulator" search on YouTube shows various simulator applications for entertainment or learning. These are often low-level simulators, although, some of them include a motion system as well, making them a mid-level simulator. Driving simulators were used to conduct driving training in countries such as the Netherlands (SWOV 2020), the UK, Finland (Sætren, Lindheim *et al.* 2019, p. 1669), and New Zealand (driving 2021). However, the use of simulators in Norway is both limited and restricted (Sætren, Lindheim *et al.* 2019, p. 1669), and are only allowed to provide driving training in an alternative way (Amdahl 2020). The following sections will describe an example for each simulator level.

Example 1 - a low-level simulator at Nord university

Figure 2.3 shows a simulator that was used to conduct a study (Eriksen 2021) at Nord university. The rig setup consists of three 2D monitors, a racing seat, a steering wheel, a gear, and pedals. The monitors were placed in a 120° FOV in front of the driver. The simulation was run by a PC, and did not include a motion system. Thus, puts the simulator in the low-level category. The research conducted using this simulator is described in Section 2.5.3.

Figure 2.3: A driving simulator at Nord university. The image was taken from (Eriksen 2021).

Example 2 - Mid-level simulator at Way

Way is one of few driving schools in Norway, which conducts driving training and research by utilising high fidelity driving simulators of research quality. However, they developed a mid-level VR simulator for testing purposes, which is shown in Figure 2.4. This solution was the testing tool for this thesis, and had shortcomings, due to being in the early implementation phase. A list of its specs are described in Section 3.3. Disclaimer, the simulator is an experimental simulator demo, with the purpose to test the potential of current VR technology, and does **not** represent the quality of other simulators at Way. For more information about other simulators at Way, see Section 2.5.4.

Figure 2.4: The VR simulator at Way, which was used to conduct the test in this thesis.

Example 3 - High-level simulator at Sintef

The study (Engen 2008, p. 21) utilised a full-scaled vehicle, and a motion system. The simulator offered a 180° FOV forward, and a projector screen was placed behind the car. The blind zones were not covered by the projector screens, as shown in Figure 2.5.

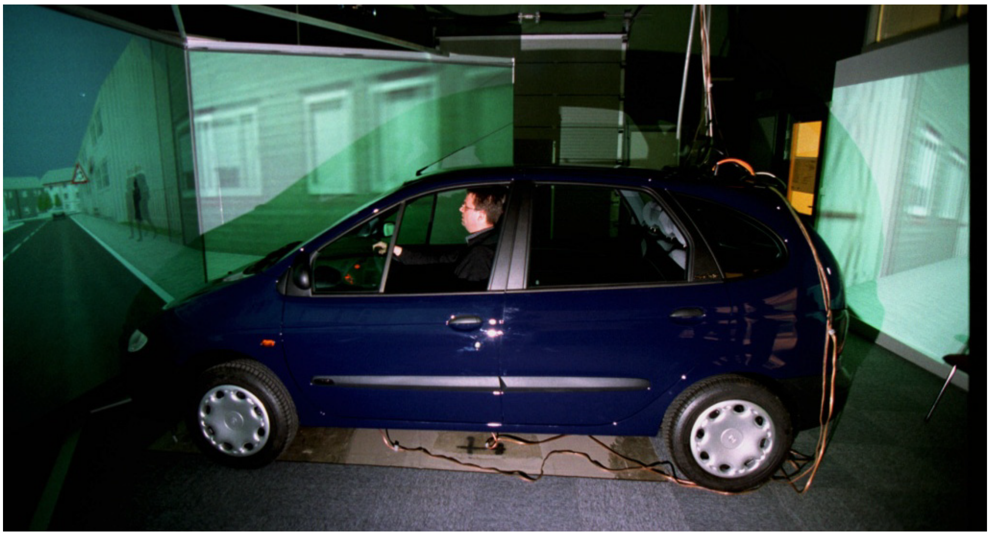

Figure 2.5: A high-level driving simulator at Sintef utilising a full-scaled car. The image was taken from (Engen 2008)

2.2.3 Disadvantages of learning to drive with a VR simulator

To start of, the feasibility study (K. Robertsen *et al.* 2020) presents some challenges related to cost and maintenance. Although, a VR headset is less costly than a full-scaled car, there are still costs related to the design, development, and maintenance of the simulation. For example, the simulation must be (re)designed to support VR. The staff needs to be properly trained to apply the simulator in their teaching, and the teaching methods must be adapted to support a VR simulator-based approach.

The study (SWOV 2020) describes possible disadvantages when learning to drive with a simulator using a high fidelity simulator. Using (Groeger 2000) as evidence, it suggested a concern where "[..there is no transfer if the learning environment clearly deviates from reality.]" (SWOV 2020, p. 3-4). Furthermore, it claims that a high fidelity simulator is too expensive to be used for driving training, as it is far from perfect to imitate the real world, even when it is of high fidelity. Thus, opposing the idea to use simulators for driving training, due to being too costly.

In addition, the study mentions another potential problem, which was the "[..retention of what has been learnt, or the extent to which it sinks in..]" (SWOV 2020, p. 3-4). It suggested that skills are acquired much quicker in a structured training, than when they are learned more or less incidentally. What has been learnt, is forgotten quickly if it is not applied immediately. Learned knowledge from incidentally scenarios in practice, sinks in, and is mastered considerably better. Although, there has been little study on problems with the transfer of learning and the retention of knowledge, which means these claims are somewhat weak. Lastly, the document describe potential problems related to SS, in which, it concluded that experienced drivers were more prone to SS than inexperienced drivers. This is related to the sensory theory described in Section 2.4.2.

The article (Sætren, Pedersen *et al.* 2018) focused on potential challenges and benefits for simulator training in the driving education. It introduced software and hardware challenges related to the development of a high quality simulator. For instance, the "car-feel" was one of the criteria that a student had to undergo in the basic traffic course, but how can a simulator be designed to provide this? (Sætren, Pedersen *et al.* 2018, p. 2047-2048). The article presents difficulties related to the adaptation of a simulator-based training in the Norwegian driving education. Additionally, it describes how the risk of SS influences the simulator's usefulness in a negative way.

In Norway, there exist legal challenges, which prevent the use of simulators to complete mandatory driving activities. For example, it is said that "[The mandatory driver's education is regulated such that it must be given by professional driver instructors while the driver learners are sitting behind the wheel of an actual car. Hence, training in simulators can only be seen as an additional part of an education program and not a part of the mandatory education.]" (Sætren, Pedersen *et al.* 2018, p. 2048). Thus, simulators can only be legally utilised to provide an alternative learning approach, outside the mandatory driving training activities, as of 2018.

The study (Sætren, Birkeland *et al.* 2019) presents a concern, where a learner driver was not willing to pay for an instructor-free lesson, as a consequence of a simulator-based teaching approach. "[An illustrative quote was: "the learner driver seemed more interested in trying it out in real life traffic]". (Sætren, Birkeland *et al.* 2019, p. 3). If a simulator-based approach discourages consumers to pay for simulator lessons, it will influence the economic gain negatively. Thus, the profit from simulator lesson depends on user acceptance.

2.2.4 Advantages of learning to drive with a VR simulator

Simulators can conduct research that would otherwise not be possible in the real world, due to ethics, and physical restrictions. For example, Sintef conducted a comparison study (Jenssen, Helland *et al.* 2013), with the goal to establish and validate a driving simulator method for assessing drug effects on driving. It is unacceptable to allow drugged drivers on the road for research purposes, if it puts others at risk. Additionally, the simulator experiment resides in a controlled environment, where confounding variables can be controlled in the simulator environment. This ability leads to more accurate measurement and estimates of effects (Engen 2008, p. xii).

Compared to traditional driving, simulators provide a more sustainable solution, as they reduce pollution, airborne dust, microplastics from tire wear, and noise (Kole *et al.* 2017) (Sportillo *et al.* 2018, p. 102-113) (Pathak *et al.* 2008, Pages 3892-3898) (Agency 2016) (Amdahl 2020).

The study (Sætren, Birkeland *et al.* 2019) suggested that a simulator offered the opportunity to provide a less stressful (K. Robertsen *et al.* 2020, p. 55), and a safer (SWOV 2020, p. 3) (Sætren, Pedersen *et al.* 2018, p. 2047) (Amdahl 2020) learning environment. Inexperienced drivers can find the initial learning phase overwhelming when on the road with others, because their potential misjudgement can hinder traffic. Thus, they creates more stress and irritation for the users in the vicinity. Besides, simulators provide a safer work environment for the driver instructor as well, as it is unacceptable to expose the student for hazardous situations that put themselves, or others at risk, due to the student's lack of experience. Therefore, students would receive insufficient training in dangerous traffic scenarios, as the driving instructor is restricted by ethics. On the other hand, this does no longer pose a risk in a virtual environment (K. Robertsen *et al.* 2020, p. 17-18). Moreover, training in a simulator beforehand, resulted in less hours on the road to master certain techniques. Spending less hours on the road, reduced the cost of the driving education for the student (Sætren, Birkeland *et al.* 2019, p. 3251).

The study (SWOV 2020, p. 2-3) used a high fidelity simulator to suggest theoretical advantages when learning to drive in a simulator, and used (Dorn 2008, p. 337-348) as reference for listing possible advantages. For example, the demonstration of manoeuvres. During a practical lesson, the instructor tells the learner how to act, but would rarely go behind the wheel to show how a certain manoeuvre should be performed. A simulator offered the opportunity to demonstrate manoeuvres first, and improves the possibility for feedback from different perspectives. Moreover, Fuller claims that it is impossible to learn without feedback, and that driving simulators offer the possibility to give visual feedback while a learner is driving. He further suggested that simulators faster expose students to a wide variety of traffic situations- compared to the scarce amount of lessons in real life traffic. Scenarios were made to offer many educational moments in a brief period of time. As the lesson is simulated, the driving instructor can offer the student with unlimited repetition, if the simulation is designed to be stage-managed, or offer the option to rollback time (Amdahl 2020). Besides, a learner's performance can be measured very accurately and objectively through a computerised, objectified assessment, in contradiction to a driving instructor's clinical observations.

Moreover, potential gains and challenges related to simulator training was also presented by the study (Sætren, Pedersen *et al.* 2018, p. 2046-2047). Note that these suggestions are potential, as "[There have not been many empirical studies measuring and discussing the learning outcomes from using simulators in the driving education.]" (Sætren, Pedersen *et al.* 2018, p. 2046). The following empirical studies had challenges in isolating, and measuring the learning outcome to determine the transfer ability. Even so, results show no significant difference in the outcome between the two test groups in the comparative study (Sætren, Lindheim *et al.* 2019). Furthermore, with the study (Happee *et al.* 2012) as reference, it appears that "[..better driving simulator performance increased the actual driving skills on the roads..]" (Sætren, Pedersen *et al.* 2018, p. 2046). Furthermore, it seems that commentary training in a driving simulator improves responsiveness to hazards on the roads (Chapman *et al.* 2012). The last study, conducted by the Germans, showed a training period that was reduced by 21 days, when using a simulator instead of traditional training with an instructor (Reindl *et al.* 2016).

Flexibility was another advantage suggested by (Amdahl 2020) and (Sætren, Pedersen *et al.* 2018, p. 2047). The driver learners train in different road traffic environments at any time of the year, as most simulators are indoors. This offered driving schools the opportunity to conduct, for instance, the night driving training independently of night hours. Furthermore, the large road traffic density variance in Norway often results in long journeys for driving schools in rural areas to access urban traffic. In comparison, this is more obtainable in a simulated environment. As for weather conditions, it is not unlikely to never experience a certain condition such as rain or fog, which makes a good argument for the use of simulator (Sætren, Pedersen *et al.* 2018, p. 2047). Targeted training where the student only practice on what they struggle with, would be more satisfied for a customer, if they received the specific training they paid for. Traditionally, it can be difficult to find the desired topic to train in real traffic conditions during a driving lesson. In a simulator, the desired time, traffic scenario, weather, and driving conditions can be stage-managed.

Another interesting aspect presented by (Sætren, Pedersen *et al.* 2018, p. 2047) is how the rapid technology advancement introduces new features in the automobile industry. Should the newly educated drivers be required to handle the basic technology found in every car, or have learned how to use and interact with new technology introduced in new cars to assist the driver? For drivers to keep up with the new technology releases, it would require a rapid change of cars. However, in a simulator, this technology can be introduced through a software update, which is a much cheaper alternative. This is not only beneficial for the new drivers, as experienced drivers can use simulators to train their driving skills to be up-to-date with the newest available features.

Past research at Way showed promising results, when conducted using their high fidelity simulators (Amdahl 2020). Collectively, these documents suggest that a driving simulator increases popularity, because young adults think technology is cool. Additionally, they prefer to try simulations, as the lack of responsibility in video games is more tempting. Thus, shows a positive public opinion on the gamification of driving training. The legal age for driving practice in Norway is 16 years, but a driving simulator allows them to train earlier. Additionally, there is the opportunity to give a more empirical learning approach instead of traditional lectures. For example, muscle memory is taught through moving muscles, regardless of the environment. A VR simulator lets students practice the preparation sequences that require a lot of attention when not automated, such as muscle memory. Compared to real traffic, there is no real danger when practising sequences in a simulator. Thus, the students can practice these sequences using more of their attention, which will let them learn more and faster, without exposing themselves and others to unnecessary danger (K. Robertsen *et al.* 2020, p. 17-18).

Today, traffic schools are all responsible to follow the guidelines for the mandatory activities, but are otherwise free to choose the method or approach to ensure the best learning process. If the driving exercises in a simulator-based approach were designed to follow the NPRA's guidelines, it would help standardise the driving education to give all students the same background, regardless of where they live or which driving school they choose. A standardised course design on a national level is the next step towards a standardised driving education.

A feasibility study (K. Robertsen *et al.* 2020) suggested that a VR setup has better mobility compared to most high fidelity simulators, as it is wireless (K. Robertsen *et al.* 2020, p. 31). When it no longer requires to be connected to a computer, it offered the opportunity to be brought to a classroom or a car, where the teaching can be conducted.

2.2.5 Summary of possible advantages & disadvantages

Potential advantages and disadvantages for using a simulator are summarised in Table 2.1.

Table 2.1: Potential advantages and disadvantages by using simulators.

Advantages	**Disadvantages**
Allow research and training in hazardous environments	High quality simulators are too costly compared to what they can offer
Provide a safe, and less stressful learning environment	Issue with the retention of knowledge
Let students train earlier, as legal age in Norway is 16 years	Issue with the ability to transfer the knowledge from the simulator to the on-road
Confounding variables can be controlled	Lacks "Car feel"
Do targeted training	Difficulties related to the adaptation of simulator-based training
Unlimited repetition	Risk of simulator sickness
Safe work environment for driving instructors	Legal challenges (Norway)
Cheaper for driver learners	Its viability and economic gain depends on user acceptance
Spend less time training	
Demonstration of manoeuvres	
Improves the possibility for feedback from different perspectives	
Faster exposition of wide variety of traffic situations	
Computerised and objective assessment	
Help standardisation on national level	
Offers flexibility, as road conditions, traffic density, environment, weather, time etc. can be stage-managed	
Offers availability, as the night driving course can be completed at independently of night hours	
Reduce driving instructor to student ratio, which increases the economical gain	
Driving instructors can monitor remotely	

Continued on next page

Table 2.1 – *Continued from previous page*

Advantages	**Disadvantages**
Help driver learners to familiarise themselves with the latest technology available in cars	
Increase popularity for commercial gain	
Is a more sustainable solution in terms of pollution, noise, airborne dust and micro plastic	

2.3 Related work

The following sections will present related works in terms of motivation, methods, technology, results and conclusion, which are relevant to the research questions.

Nord university conducted a comparative study (R. Robertsen *et al.* 2016) on the night driving course, with the motivation to "[..examine theoretical learning outcome of night driving by comparing traditional real life training and simulator training.]". In a more recent study (Sætren, Lindheim *et al.* 2019), the night driving course was compared to traditional learning methods. A low level simulator was used in both studies. This thesis' methodology was inspired by these comparative studies, due to their target group and focus. Although, the results were promising, it was concluded that more research was needed, due to its small testing sample. Therefore, this thesis will, hopefully, supply this research with more test samples. Furthermore, examine whether the results from the study (R. Robertsen *et al.* 2016) apply for a VR simulator as well. The most recent comparative paper was conducted in 2019, which makes the results relatively up-to-date with what we know today.

Way traffic school conducted research in cooperation with the NPRA (K. Robertsen *et al.* 2020), NTNU (Amdahl 2020) and Nord university (Sætren, Lindheim *et al.* 2019). The overall goal for this research was to allow simulators to be used to pass mandatory driving exercises in the Norwegian driving education. The focus was on the practical part of the basic traffic course, namely, the night driving demonstration. The research showed potential in the testing tools, but it concluded that more research was needed. As mentioned in the introduction, the CAVE simulators were expensive solutions, excluding costs related to development, maintenance and staff training. Therefore, the research was motivated by the commercial gain from a cheaper solution, if it resulted in a learning outcome, which was non-inferior to their traditional teaching approach.

Moreover, the NPRA recently conducted a VR simulator feasibility study in cooperation with Nord university (K. Robertsen *et al.* 2020), in 2020. The study is relevant, because its goal was to examine the potential of a high fidelity VR simulator. The data was collected electronically, and linked to a VR driving game, through questionnaires and user testing. The results were based on user acceptance, learning outcome, and realism. It seems that VR positively impacted the learning outcome positively, and appeared useful in the learning progress. However, the simulator lacked physical feedback, and the study emphasises the necessary pedagogical- and technical competence to apply this solution (K. Robertsen *et al.* 2020, p. 53-55). Although, the results were promising, their solution had two major concerns: 1) the high fidelity simulator cost, and 2) no physical feedback.

Sintef was an independent research organisation founded in the year 1950, with their main office in Trondheim. Research from 2006 (Moe 2006) was conducted using a high fidelity simulator for truck driving. The simulator can be seen in Figure 2.6. Their study focused on finding different learning strategies, which would improve the quality of the training process, and the training cost efficiency. To achieve this, they used a simulator of research quality, private driving lessons, and driving lessons from a traffic school, as their methodology. A demonstration of their simulator is showed in (Sintef 2012). They ended the test process with a test to evaluate the competence for step 2 in the Norwegian driving education. It was concluded that the simulator used in this experiment was an effective pedagogical learning tool to train students in the step 2 of the Norwegian driving training education. This paper was conducted in 2006, and applies simulator-based training outside the basic traffic course. However, I find this study relevant, because it contributes to the common goal of a simulator-based driving education in Norway. If this study shows promising results with available technology at current time, assuming technology improves as time passes, the results from today's studies should be non-inferior to the results in this article.

In Sintef's more recent research, they utilised VR technology in their VR-lab, with the main focus on tunnel development and training (Sintef 2020). Appendix C shows a full list of their areas of activity, which was taken from a VR-lab presentation by Dr. Gunnar Jenssen. For example, the study (Jenssen, Skjermo *et al.* 2020) was conducted using a low-level VR driving simulator, to examine safety and visual measures for driving in long tunnels.

A pilot project conducted by Hirsch and Bellavance (Hirsch and Bellavance 2016b) investigated the validation of transferring the training learned in a high fidelity driving simulator to on-road driving. The study (Hirsch and Bellavance 2016a) is their final report on this long-term study. They focused on the transfer of skills learned on a driving simulator to on-road driving behaviour, as its title suggested. It was "[A long-term, naturalistic, prospective-cohort transfer of training study..]" (Hirsch and Bellavance 2016a, abstract). The study adopted a practical approach

Figure 2.6: A high fidelity simulator was used to conduct truck driving training in Trondheim. The image was taken from the Sintef demo (Sintef 2012).

suggested by (Parkes 2005), consisting of three important elements "[..that should drive decisions on simulation provision within the training process]" (Parkes 2005, p. 6):

1. The efficiency and acceptability of the learning in the simulator.
2. The transfer of the learning to the real world.
3. The retention of skills or knowledge learned.

Their methodology consisted of questionnaires, driving simulator data, and records from the Quebec Automobile Insurance Company. For the first element, they developed and tested "[..a reliable method for implementing driving simulator-based training in driving schools and measuring how learner drivers perceived their driving simulator training.]". The second element "[..was objectively measured by performance on the probationary permit road exam.]". The third element was "[..was objectively measured by driver records of infractions and crashes during the first months and years of unsupervised and relatively unrestricted driving.]" (Hirsch and Bellavance 2016a, p. 10). A VS500M high fidelity driving simulator, and a survey study method consisted of two questionnaires was used to conduct the study. It was concluded that driving simulators "[..provide safe learning situations and have great potential to help drivers acquire skills that will help keep them safe in the transfer situation, i.e. the real road.]". However, the transfer of learning depends on the presence and correct location of the learning situation elements, which must be identical to the same elements on the real road. In simpler terms, the simulation must include elements, which are identical to those experienced on a real road. Furthermore, the study claims that "[..it appears the majority of driving skills, particularly those skills associated with reducing the risk of involvement in intersection crashes, require the use of a driving simulator with a minimum visual system consisting of no less than a 180-degree forward FOV plus rear-view mirrors and blind spot displays and geometrically accurate representations.]" (Hirsch and Bellavance 2016b, p. 79). The paper is relevant, as it focus on the validity of the transfer process from a simulator to the real life, which must be included in the evaluating of a driving simulator as a learning tool. Its long-term research study validates its quality and relevance, even though it was conducted in 2016.

A recent study at NTNU (Engen 2008) did also investigate the use and validation of driving simulators. Its goal was to collect data, such as information about driver behaviour in traffic. In addition, it was motivated by a special need to look at the validity of a driving simulator as a research tool, to support further research. The main focus was to compare the research and the results from available sources. The study used roadside equipment, and instrumented vehicles for data collection. Its methodology consisted of field studies, observational studies, and extensive documents. It was concluded that driving simulators were steadily becoming an important research tool, and simulators were cheaper, and more widely available, due to the advancements in computer science. Although, it suggested that a driving simulator cannot replace other research or measurements, it is a valuable addition (Engen 2008, p. 126). Moreover, "[..The differences between real world results and driving simulator results, were generally not larger than the variances in real world results..]" (Engen 2008, p. 127), despite the arbitrary permutations found in the real world.

The study (SWOV 2020) suggested minimum requirements to allow a simulator to be used for driving training. Firstly, a good imitation is needed to ensure optimal transfer of learning. This is why technical quality determines a simulator's usefulness for driving training. Secondly, whether a student learns, depends on the quality of simulator lessons as well, which requires driving schools to design a good curriculum for the simulators' educational effect to be optimal. Thirdly, the training objectives must be clear, and it must be possible to test whether these objectives are achieved or adjusted to the pace and learning style of the individual learner (SWOV 2020, p. 3-4).

The BMW group conducted several studies involving simulators. The study (Ihemedu-Steinke, Sirim *et al.* 2015) had the goal to develop and evaluate a VR driving simulator for future automotive HMI concepts. This was done using the Unity3D game engine, the Oculus Rift headset, and a low level simulator. A questionnaire survey was conducted as their methodology. It was concluded that "[..its level of immersion was limited due to the occurrence SS caused most probably by a motionless simulator, poor graphical performance of the driving scenes, incorrect scaling of the perceived speed and acceleration as commented by most test drivers..]" (Ihemedu-Steinke, Sirim *et al.* 2015, p. 498). It was decided to continue the research, because of the benefits provided by a full VR solution. A more recent study (Rangelova and Andre 2019) were conducted to examine possible causes, and to find possible solution to SS cases in the previous study, when utilising a VR HMD.

In 2017, a study (Ihemedu-Steinke, Rangelova *et al.* 2017) conducted an experimental post-test to examine SS related to a VR driving simulation. The goal was to investigate preventative measures for SS, by answering eight hypothesises. This was motivated by the lack of research on this area. Here, they investigated how the use of limited or full visual assets (VA) in the simulation, impacted the risk of SS symptoms. A survey consisting of questionnaires, and a low level VR simulator were used as their methodology and technology. The results were based on a simulator without a motion system, which means that a lower probability of SS in this thesis' results would be promising for the VR simulator. The most significant conclusion was that "[..additional VAs can play a role in reducing SS in VR driving simulators and enable participants to stay in the virtual environment for a longer time..]" (Ihemedu-Steinke, Rangelova *et al.* 2017, p. 17). Finally, it implied that "[..future studies should look into [..] the integration of a motion platform..]" to reduce SS (Ihemedu-Steinke, Rangelova *et al.* 2017, p. 19), where this thesis, hopefully, contributed.

2.4 Related theories

This section presents theories related to the pedagogical aspect of simulator applications, and SS.

2.4.1 Driving simulator as a learning tool

The empirical nature of driving simulator, emphasises the "learning by doing" principle. Katrin Becker conducted a book review (K. Becker 2005) of a comprehensive guide to simulations, computer games, and pedagogy in e-Learning and other educational experiences, by Clark Aldrich (2005). Clark Aldrich "[..tackles the *who*, *what*, *where*, *when* and *why* of educational experiences that involve the use of computer simulations and games.]", and expresses that "[..For some types of learning, computer games and simulations are clearly the best approach we have available. Simulations can be a key (perhaps even *the* key) ingredient in the transformation of all learning from the more formal and prescribed models of the 20th century, to the individualized, engaging experiences of the 21st century..]" (K. Becker 2005, p. 1). Although, Clark includes interesting theories in his guide, his book "[..does not contain many formal references to other works within the text..]" (K. Becker

2005, p. 3).

Kolb's experiential learning

Kolb suggested learning is an ongoing process through experience, which he created a model called the experiential learning model. Simulator-based training implies a "learning by doing" approach, because of their empirical nature. The model characterise the learning process as a four-stage cycle. I have taken the liberty to assign a number to represent each stage for reference, which is shown in Figure 2.7. Although, this is not always the case, the cycle usually starts with a concrete experience. From this, the brain forms abstract concepts and generalisations. These concepts can be tested to form new concepts, which may result in new concrete experiences. Thus, the cycle continues.

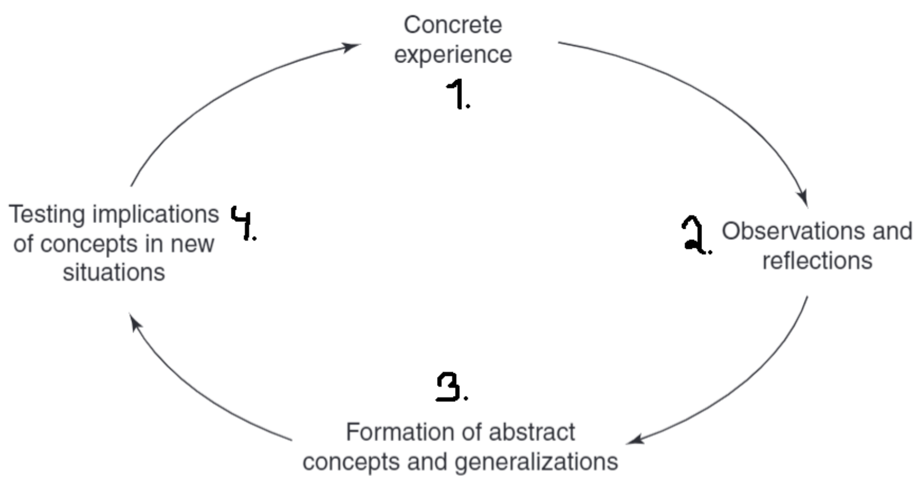

Figure 2.7: Shows the four stages in the cycle. The image is taken from (L. R. Becker and Hermosura 2019).

The article (L. R. Becker and Hermosura 2019) presents a more detailed description of each step in the Kolb's experiential learning model, when applied in a medical context. Assuming a learning process is not restricted to a field of study, the focus of this section is to describe how this model can be applied in a simulator context for one iteration. Keep in mind, a student may go through one or several cycle iterations throughout a night driving course.

To start of, imagine a student in the night driving course, which consists of lectures, practical activities, and a demonstration. Throughout the activities, the student receives concrete experiences from certain events, which puts their learning cycle process at stage 1. For example, a car activates its long beams, and the student experience how their line of sight has been increased in the dark. If the student were to learn from this, they would need to observe and reflect on this fact, which puts them in stage 2. Their ability to reflect around presented topics, lets them form abstract concepts or generalisations in stage 3. For instance, they form a concept where their line of sight in the dark, depends on the type of light the car uses. To verify this idea, the student have to test their implications and concepts. In this case, toggle the lights to short beam to see how this influences their line of sight. The student observe how a car with short beams provides a reduced line of sight, compared to long beams, and learn from this, which put them in stage 4. This may create a new concrete experience, which starts a new learning iteration, thus, the learning cycle is continuous. The core principle of the driving training is to make driver learner able to train, and reflect on their actions when on the road. This model shows an overview, which can be used when evaluating the learning outcome from driving training.

2.4.2 Simulator sickness

Simulator sickness "[..is a well-known phenomenon that has physiological effects on users, such as disorientation, headache, and nausea.]" (Rangelova and Andre 2019, abstract). The article (Ihemedu-Steinke, Rangelova *et al.* 2017, p. 6-7) suggested three theories, which explains these physiological effects in a structural manner:

The sensory theory - if there is a mismatch between body- and perceived motion, the brain becomes disorientated, and will think it is due to hallucinating, because of toxic indigestion. To remove possible toxins, the body may trigger a defence mechanism, such as vomiting. For instance, when motion is perceived inside the virtual world, but the body stays in a still position.

The neural theory - if there is a mismatch between received sensory information and past experience, it may result in a headache. For instance, exposing subjects to a badly represented traffic situation, which conflicts with the subject's expectations based on previous driving experience.

The postural instability theory - the main goal of humans is to maintain stability, and when the balance is lost, we feel nausea. For instance, a driver may attempt to resist the tilt on a curvy road, which is visually perceived in the simulation. This attempt might disrupt the driver's stable position, which causes postural instability, because there was no physical tilt experienced.

2.4.3 The technology acceptance model

The technology acceptance model describes how the perceived ease of use and usefulness are connected to the intention to use, which is required to create user

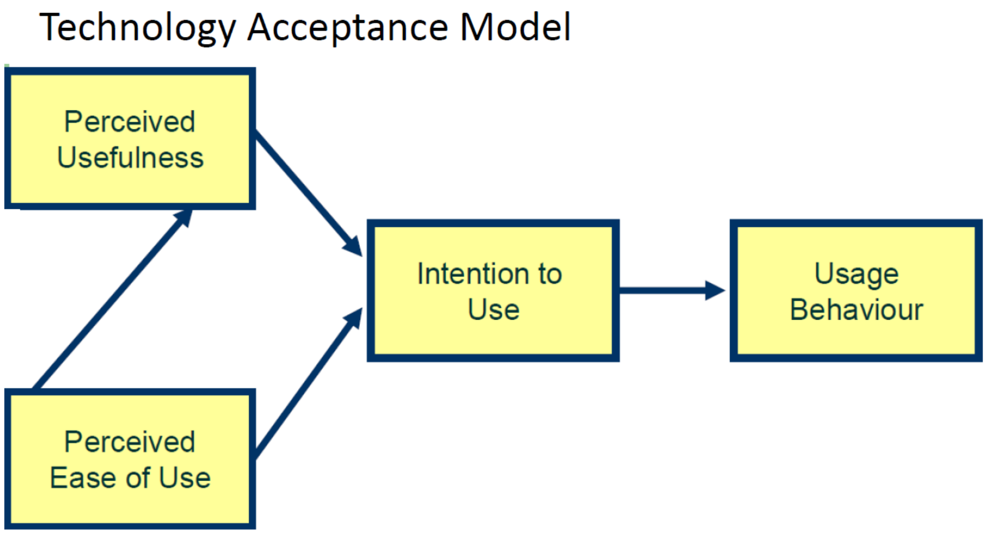

Figure 2.8: An overview of the technology acceptance model. The image was taken from the lecture slides in the course IT3906, NTNU.

behaviour for a system.

2.5 Driving training in Norway

2.5.1 The GDE matrix

The goals for driver education (GDE) is the result of a EU project, which was conducted in 1999. This model has "[..been widely acknowledged by the traffic research community as a promising theoretical starting point when developing driver training..]" (Hirsch and Bellavance 2016a, p. 8). The learning plan for vehicle category B is designed to include elements from the GDE matrix, as it lays the foundation for all traffic training in Norway. This matrix describes 5 levels in the development of driver skills and traffic knowledge, see Figure 2.9 for the Norwegian version.

2.5.2 The training process

To get the license, a driver needs to complete certain mandatory activities in an extensive stepwise program consisting of 4 levels, both theoretically and practically. In addition, the driver must fulfil health requirements, and conduct a criminal record check. To see the learning plan in full detail, the handbook is available online at the NPRA's website (Vegdirektoratet 2016). The mandatory steps in the handbook for license class B, is summarised as follows:

Step 1 - Basic traffic course - introduces the students to the fundamental factors of being a driver. The goal of this step is to make the student understand the

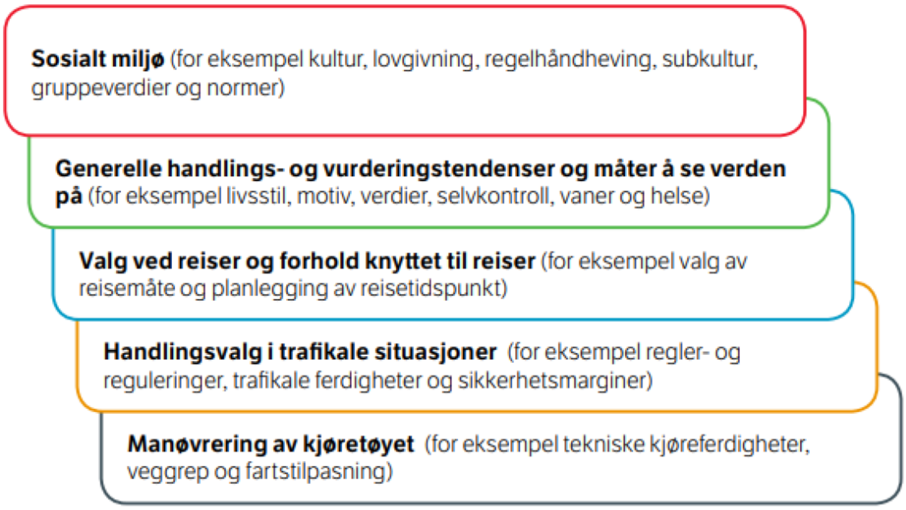

Figure 2.9: The goals for driver education (GDE) matrix. The image was taken from (Vegdirektoratet 2016, p. 12)

meaning of the road traffic act 3 (Transport 2011), which is the fundamental principle for safe driving. This step includes the night driving course, which is the main focus of this paper. After completing this step, the student is expected to have a basic understanding of traffic theory, and be able to evaluate their own competence to begin step 2 training.

Step 2 - Basic training (vehicle and driving skills) - through this course, the student should be able to master the technical aspect of driving without the need to pay attention to other drivers. The goal of step 2 is to give the student the foundation to get maximum yield from step 3. In addition, the student should be able to move the attention away from the vehicle, and focus on the traffic image and other traffickers. Similarly to the basic traffic course, the student should throughout the course discuss their own motivation and willpower to use the knowledge and skills they learn in the course. Lastly, evaluate their own skills to use, and detect failures with the car.

Step 3 - Proficiency in traffic - the goal of this course is to learn the student to drive clearly, safely, and independently in various traffic. The student has to pass the safety course on track to move up to the next step. Also, as in the previous steps, reflect and discuss their own motivation, their will to use the knowledge, and the skills they have learned in this step. Lastly, evaluate their own skill to drive in cooperation with others.

Step 4 - Final training - the purpose of the final training is to bring the student to the main goal of driving training, which is to acquire sufficient driving skills to continue the training independently. This includes a safety course on road, long-distance driving, and extensive practice driving.

To proceed from one step to the next, a driver instructor must verify whether the learner driver is qualified. Lastly, the student must pass a theoretical, multiple choice exam after step 1, and a probationary permit road exam after step 4. The student receives the license when they pass all mandatory activities.

2.5.3 Motivation to use driving simulators

Norway is in the early phase of applying simulators in the driving education, as simulators are not yet allowed to replace any parts of the mandatory driving training. Only 5-10 of over 1000 driving schools in Norway applies driving simulators to support their education process, which means that the commercial interest is currently low. The reason is due to the fact that Norway has one of the most strict traffic educations in the world, and results in strict requirements to approve simulator-based traffic training. Despite this, the NPRA, as the representative for the public sector, was interested to approve simulator-based training, if the simulator provided the necessary training according to the NPRA's driving training guidelines (Vegdirektoratet 2016). This shows the motivation for simulator-based learning in Norway.

2.5.4 How driving simulators are utilised as a learning tool to conduct driving training at Way

Way is one traffic school in Norway that focus on the use of simulators to improve driving skills as quickly as possible. To accomplish this, they have applied a top-down approach, where they invested in high level driving simulators at first, and then looked for cheaper alternatives.

Way have multiple offices in Norway, but the focus was on their main office in Trondheim. In addition to the driving teachers, Way's main office include a developer team, which was responsible to develop and maintain the courses for their simulators. Figure 2.12 shows one of the two CAVE simulators that are installed, which are used to provide driving lessons in an alternative way at present date. Each simulator consists of a car that is connected to a motion system. The car is surrounded by a wall, which is used by projectors, and a TV screen is mounted on the rear window, see Figure 2.10. Collectively, these offer a 360° view of the environment, see Figure 2.11. To minimise the difference between the car- and the simulator feeling, there have been minimal changes to the cars in the simulators. For instance, the brakes are original from the factory. When the driver brakes, the motion system moves the car according to mathematical calculations based on the

Figure 2.10: A monitor is mounted at the back of the car's rear window in Way's CAVE simulators.

Figure 2.11: The rear-mounted screen and projected walls offer a 360° panorama view of the environment.

pedals' force input.

How are these CAVE simulators used to conduct driving training? When a student arrive for the first time, the driving instructor describes the learning goal for the lesson, and explains the steps in the exercise to prepare the student for the simulator experience. Then, the student is free to enter the simulator alone or together with a driving instructor. While the student is driving, the driving instructor's role is to monitor and guide the student to the end of the exercise. When the student is driving alone, the driving instructor monitors the student from a base station, see Figure 3.1. The driving lesson is recorded, analysed, and used by the instructor as a basis to discuss potential improvements to the student's driving skill after the driving lesson. Additionally, the base station provides a two-way communication between the student in the simulator, and the driving instructor.

Figure 2.12: A CAVE simulator at Way that is used to conduct driving training in an alternative way.

All simulators run scenarios, which cover driving on different type of road, for instance, in urban and rural environment. Also, they provide the opportunity to drive in the dark, on snowy- or frozen roads, in rainy or foggy conditions. The CAVE simulators uses the same car model that are used on-road with instructors, to make the most out the training, and to minimise the time the student spend to adapt a new car (Amdahl 2020).

Chapter 3

Methods

To achieve the research objective, a supplementary survey study with crossover randomised controlled trials (RCT) was conducted.

3.1 Ethics

The survey study was approved by the Norwegian Centre for Research Data (reference number 696408).

Approval to conduct the survey study was sought and given to the test subjects involved. Additionally, the test subjects' providers or parents were involved in the approval for subjects under the legal age. The traffic school was involved in the recruitment and partly in conducting the trial. All ordinary procedures at the test subjects were followed for ethical reasons, and to ensure to uphold the privacy concern for all involved parties. All participants, and their respectively parents or providers were informed in writing, and orally upon request, of their rights and the purpose of the study, including the participant's right to withdraw without providing a reason. Written consent was obtained from all participants, and the study was approved by the traffic school administration. The approval contract is showed in Appendix I.

3.2 The survey study

The objective of the survey study was to examine if the learning outcome from a VR simulator was non-inferior to the learning outcome gained from a traditional approach. Therefore, a non-inferior hypothesis was a natural choice. It was decided to evaluate the learning effectiveness from the VR simulator, and the traditional approach, in terms of learning outcome that was gained from these. Therefore, data collection and data analysis methods were chosen based on the learning outcome as the data type.

It was conducted a survey, which consisted of questionnaires, due to their benefits suggested by related research. A digital questionnaire service was used, which made it easier to deliver the forms to a large target group, manage invites, offered the opportunity to reach most people, and extracting the data was more or less effortlessly. Furthermore, a digital service was more accessible, as it supports multiple platforms, such as a PC or mobile, and was not restricted by a specific time or an appointment. Therefore, a survey consisting of questionnaires was seen as a reasonable method, and was chosen in this thesis. Section 5.4.1 discusses other methods, and why they were not chosen in this thesis.

It was decided to focus on the traffic candidates that took the basic traffic course and/or the night driving course at Way. These test subjects had little or no prior knowledge, which provided the desired diversity.

The survey offered the opportunity to answer all research questions. In the experiment, a VR simulator was applied in an educational context, as a learning tool. I hope to answer **RQ1** by comparing the results to existing research, where a driving simulator was utilised as a learning tool. To answer **RQ2**, reported cases of SS in the test results was compared to existing research to evaluate how the motion system influenced the risk of SS. Hopefully, the results from the test case helps answering **RQ3** about whether the learning outcome from a VR simulator is non-inferior to the traditional teaching approach, when conducting the night driving course.

3.2.1 Design

There exist related studies for comparing the simulator- and the traditional approach (Sætren, Lindheim *et al.* 2019) (R. Robertsen *et al.* 2016), the transfer of skills (Hirsch and Bellavance 2016a) and for examining preventative measures for motion sickness (Ihemedu-Steinke, Rangelova *et al.* 2017), which all utilised surveys, consisting of questionnaires, for data collection. Therefore, a survey design was a natural choice. The intention was to investigate the potential of VR technology as a learning tool, by comparing its effectiveness with a traditional teaching approach. In addition, measure potential cases of SS with the current testing tools. With the goal to supplement existing research with more test samples, it was decided to conduct the study as a supplementary survey study.

The amount of acquired learning outcome was used to measure the effectiveness of a learning approach. To measure the learning outcome gained from the approach alone, there was a need to measure the knowledge level before and after conducting a night driving training course. The survey consisted of four questionnaires. Two before each course (pre-Q), and two after each course (post-Q). The retention of knowledge was a concern suggested by (Hirsch and Bellavance

2016a, p. 65), which is why it was decided to measure the test subjects' attitude and awareness in traffic, in all questionnaires. The purpose of the pre-Qs was to collect data about the test subject's prerequisites, in terms of traffic awareness, course expectations and past experience. The post-Qs were designed to collect data about the test subject's current traffic awareness, and to measure their knowledge level through subjective- and objective assessment.

The subjective assessment was included in the post-Qs, due to the subjective nature of learning, and the study's (Sætren, Lindheim *et al.* 2019) methodical implications. In addition, this offered the test subject's the opportunity to reflect on their learning, which is a part of the learning process according to Kolb's experiential learning model, see Figure 2.7. Moreover, the comparative study suggested a test after each course to measure the learning outcome objectively. To prevent the evaluation of the overall learning outcome to be solely based on user bias, it was conducted an objective assessment of the learning outcome through a multiple choice test. Therefore, the total learning outcome was represented by a subjective- and a objective assessment. The learning goals, and the multiple choice test questions were formed, by consulting the traffic administration at Way, to ensure they were up-to-date with the current traffic curriculum.

In the study (R. Robertsen *et al.* 2016), participants were randomly distributed into two groups, which conducted the night driving course in a simulator and by traditional means, but in different order. This approach was reasonable to avoid false positives due to the repeated learning factor. If a group was introduced to the same learning concepts for the second time, thus, give them more time to digest the same learning concepts, their learning outcome would naturally increase. Therefore, this approach design was chosen for this thesis as well.

All questionnaires included practical information, and a question similar to "Have you completed a night driving course in VR prior to this questionnaire?" to keep track of the order, which the questionnaires were answered. For example, those who said "no" in the VR questionnaire would automatically be assigned to group 1, and the rest would be assigned to group 2.

The SS was measured through a list of possible SS symptoms. A full list is shown in Appendix D, which was taken from a lecture slide by Mikhail Fominykh (2020) at IMTEL, NTNU. However, it was decided to include overall symptoms, which was used by related works and theories, and for simplicity, due to the young target group.

3.2.2 Participants

The test subjects was chosen arbitrary, with the only requirement that the target group were all students who attended the basic traffic course, including the night driving training courses between fall 2020 and spring 2021. They were recruited by the project manager with a presentation of the research project, which occurred at the start of the basic traffic course, or at the start of the night driving course for those who have already completed the basic traffic course. Those who had already completed the night driving course, i.e. in fall 2020, were recruited by the traffic school administration using a motivational letter.

3.2.3 Interventions

There were two interventions: a traditional practice and a VR application intervention. The traditional practices were up-to-date with the current educational process. The VR setup was developed in accordance with the guidelines for the mandatory night driving training (Vegdirektoratet 2016, p. 24) (Amdahl 2020). The overall design of the VR simulator application was implemented like the CAVE simulators in terms of assets, game- and physics engine. The application was designed to be completed individually, although, the test subjects would normally receive guidance from a driving instructor positioned at a base station 3.1. In this experiment, the test subject was not guided by a driving instructor, but was provided with a technical assistant, to ensure that they completed the course in an ordinarily fashion.

Before and after each intervention, the test subjects received a questionnaire. The participants were divided into two groups, namely, group 1 (G1) and group 2 (G2), as shown in Figure 3.2. Depending on the assigned group, the corresponding pre-Q was sent to each member, after they signed the approval contract. For instance, candidates in G1 were told to answer the pre-VR-Q before they tried the night driving course in the VR simulator (VR course), and they were instructed to answer the post-VR-Q afterwards. Then, G1 followed the same procedure for the traditional approach (RL course) with pre-RL-Q and post-RL-Q, and vice versa for G2.

The simulated night driving course consisted of two parts. Unfortunately, part two was not ready for testing. To compensate, the test subjects were allowed to drive part one two times instead. The first time, the test subjects were instructed to complete the course in an ordinary fashion. The second time, they were allowed to drive freely. Each test subject participated in a session, which lasted about one hour. The session consisted of a briefing-, a driving-, and a debriefing session, which lasted approximately 15 minutes, 20x2 minutes, and 5 minutes, respectively. The driving session was conducted for each individual in both groups, one at the time, and held at Way's main premises. I, the project manager, was available through the briefing, the simulation, and the debriefing phase. Also, I was responsible for the technical assistance. A short briefing was given orally before simulation start. While the simulator was running, the test subject was allowed to receive technical assistance, if it kept them from completing the course, to em-

Figure 3.1: A base station used by driving instructors at Way while conducting driving lessons in the CAVE simulators.

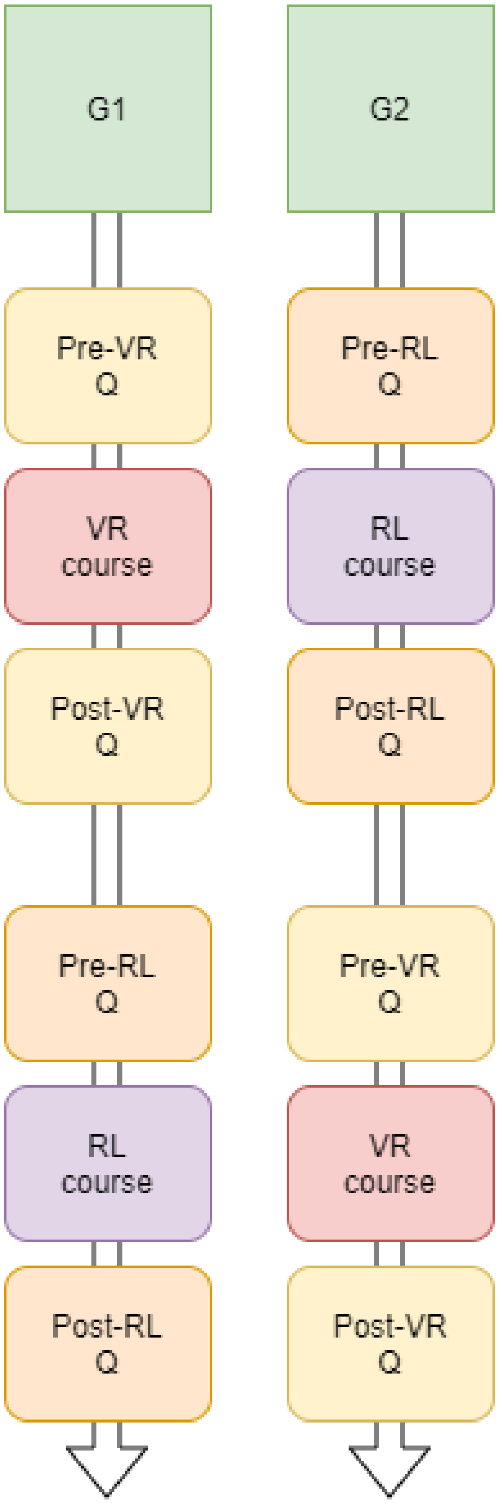

Figure 3.2: The figure shows an overview of the test process. Labels: G1: Group 1, G2: Group 2, Q: Questionnaire, RL: Real life, VR: Virtual Reality.

phasise the learning from independent driving. After completing the course, the test subject was given the last questionnaire, and given the opportunity to provide feedback on the experience to conclude the experiment. This feedback was collected to help Way to improve their simulator experience.

As previously described, the session consisted of three phases: a briefing phase, a simulation phase, and a debriefing phase. These are listed below.

1. **Briefing phase**: the test subject was given a short briefing on the different phases throughout the experiment, including the simulator's capabilities and possibilities, and what to expect in the virtual course. They were informed about the motion system, and the risk of SS, and was given the control to stop the experiment if they felt symptoms. Also, they would not receive any pedagogical help, as the course was meant to be completed individually.
2. **Simulation phase**: the simulated course was conducted approximately close to the real course, with the only difference being, they now drove independently, as shown in Figure 3.3. The overall learning goals, and how the instructions were structured, was presented at simulation start. The simulation was conducted in a traditional manner where the test subject drove through the course independently, and completed each task in their own pace. While the simulation was running, they were allowed to receive technical help, if it prevented them from finishing the course. Otherwise, they were blinded to the specific learning objective at each checkpoint, and were told to follow the instructions given by the simulation. After the test subject completed the course, the simulation was restarted, and they were told to drive freely. The simulation phase ended after approximately 40 minutes of driving or if aborted.
3. **Debriefing phase**: The test subject were debriefed immediately after the simulation phase. Here, they were able to provide feedback on the simulation experience. In addition, they were told to answer the final questionnaire, which was given after the test.

The testing process was carried out at the driver school in the afternoons, and each test subject was given an appointment to test the simulator. The simulated course consisted of a predefined training program, which was designed in accordance to the Norwegian night driving guidelines. It was decided to describe the first part, as it was the only part used in the experiment. The training program consisted of a deterministic path, consisting of a set of checkpoints. One example is showed in Figure 3.4. At each checkpoint, the test subject was presented with theoretical concepts, facts and instructions from a billboard sign, see Figure 3.5, and 3.6. The checkpoints covered topics such as: 1) Basics, 2) Meeting a vehicle, 3) Being passed, 4) Passing other vehicles, 5) Pedestrians and other hazards, 6) Roadside

Figure 3.3: The VR simulator at Way, which was used to conduct the tests. The test subject was able to drive independently through the night driving course.

parking, and 7) Roadside emergency stop. The test subject had to complete all instructions given at a checkpoint, before moving on to the next.

Figure 3.4: The lesson consisted of checkpoints, marked by a pink rectangle. The driver had to stop within the area to receive the next instruction.

3.2.4 Data collection

To conduct a statistical analysis to find common patterns in terms of learning outcome, a quantitative data collection method was needed. Data collection was performed through questionnaires using a digital survey service called Nettskjema (Nettskjema.no), which was provided by the University in Oslo (UiO). The production of this data was a demanding process, as it required to follow-up each candidate through all questionnaires in the correct order, and booking appointments for VR testing that fitted their schedule, depending on their assigned test group. Section 5.4.1 describes other factors, which influenced this process.

To present the information from the questionnaires, a spreadsheet (Microsoft Excel) was generated from Nettskjema, including answers, questions, health information, age and gender. The Appendix E (pre-RL-Q) is meant to show an example of which data was collected from one of the questionnaires, and does not present any real data. Appendix F, G and H shows questionnaire post-RL-Q, pre-VR-Q and post-VR-Q, respectively.

3.2.5 Analysis

This analysis focused on identifying common patterns between the test subjects in the results, which was linked to the results from existing documents in terms of

Figure 3.5: A billboard sign presents the driver with lessons and instructions.

Figure 3.6: The training program teaches the driver about how different light modes influences the visibility of objects or pedestrians.

learning outcome. Thus, it was decided to conduct a quantitative, statistical analysis to evaluate the quality of the real- and the simulated night driving course, which was measured by the learning outcome. The idea of the design was to compare a generalisation of the learning outcome based on their prerequisites between each group, using statistically analysis. Although, it is possible to make learning outcome comparisons when several test subjects are involved, it seems that such a comparative study would require a larger number of test subjects. Therefore, the comparison study was conducted within the range of test subjects.

Starting of, the pre-VR-Q, see Appendix E, includes the section "Attitude when in traffic", which covers the statements related to their experience and attitude in the traffic as a pedestrian, i.e. do they use retroreflectors? Moving on, the section "Expectations to the night driving course" was meant to cover their course expectations. In addition, the pre-VR-Q covers past experience and expectations related to VR technology. Furthermore, the questionnaire collects information about health, age and gender, as this information was related to the risk of SS, see Section 2.4.2, to help answer **RQ3**.

The questions related to their traffic awareness were included in the post-Qs, shown in Appendix F and Appendix H. The change in traffic awareness in the post-Qs measures how the course influenced their traffic awareness, which shows the potential in the retention of knowledge. The question "What did you learn from the night driving course?" covers the subjective assessment of the learning outcome, which was compared to their expectations. This shows if what they learned was non-inferior to what they expected from the course. This is promising if the difference is positive or unchanged, as the main problem is a non-inferior hypothesis. However, there exist learning goals, which are not included in the night driving course. These were included to verify the reliability of the data, as they were meant to prove whether the test subjects answered seriously while answering the questionnaires, or if they were merely guessing. Therefore, it was expected a negative, or unchanged difference for these statements. Next, "Experience of the night driving course" covers the evaluation of the VR simulator, as a night driving course approach. Collectively, these comparisons are meant to help answer **RQ1**, by providing data for the VR approach, and compared to the traditional approach. Finally, each post-questionnaire includes a 20 question multiple choice test, which objectively measure their learning outcome from the course. Together, these topics covers the overall learning experience from both courses, which was used to answer **RQ3**. The results from the multiple choice test were presented with mean and standard deviation. The results were analysed, by looking at the amount of correct answers, and compared between different approaches. If there are no significant difference between the test scores, it would increase the viability of the VR simulator-based approach.

3.3 Testing tools

A VR simulator was used to conduct the test for the night driving course. Figure 2.4 presents a simplified overview of the full setup. The VR setup consisted of five components, which connected the simulation to the actuators in the motion system. See Figure 3.7 for an overview of this process. Starting from the right of this figure, the game outputs telemetry data, such as *force input* data, based on physical calculations. This force input data was sent to Simtools through a local UDP server. The UDP server was configured to receive and send the telemetry data before Unity's rendering cycle, to reduce the render time delay. The contents of the UDP packets are shown in Appendix B. Simtools is a software interface between software and hardware. More specifically, between the simulation and the motion system. Upon receiving these UDP packets, it sends the corresponding signals to the servo motors based on the content of the UDP packet, which moves the actuators accordingly. This communication goes both ways, as Simtools needs to receive output data from the servos, to determine what input to send next.

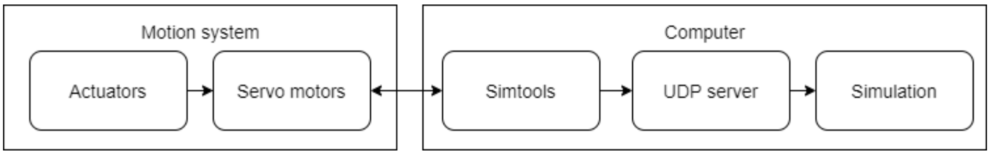

Figure 3.7: A simplistic overview of the connections between the motion system, and the simulation.

Motion system - The system was a 3DOF motion system, and consisted of three actuators, which each controlled by a servo driver. The three actuators covered pitch, roll, and yaw. See Appendix A.1 for an overview of the different DOFs. The setup is one of the driving rig setup packages, which were delivered by Prosimu. The system was controlled through Simtools, which was installed on the computer that run the simulation.

VR headset and tracking units - XTAL was used as the VR HMD, see Figure 2.1. It had a 2560x1440 resolution (5K) per eye, which was more than the average headset, and had a refresh rate of 70Hz (Wikipedia 2020). Two Valve tracking stations was placed in front of the simulator to improve the accuracy of the headset's position- and rotation tracking, see Figure 3.8.

Steering wheel, pedals and gear The "Thrustmaster T300" was used as the steering wheel, see Figure 3.9. This included pedals and a manual gear shift that was set to use automatic gear, see Figure 3.10.

Computer The computer included a 4.1GHz Intel Core i5-10600K processor, 64GB memory, and a Nvidia GeForce RTX 3090 graphic card with 24GB graphic

Figure 3.8: Valve tracking stations to improve the headset tracking accuracy and stability.

Figure 3.9: The Thrustmaster steering wheel offered a button layout similar to a PlayStation controller.

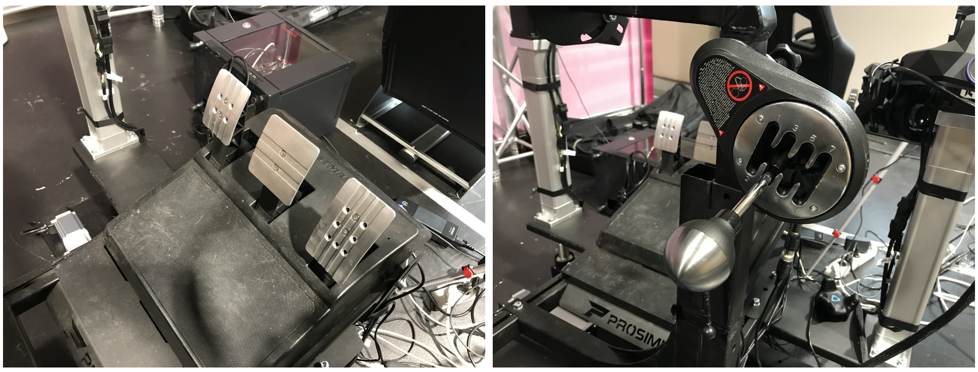

Figure 3.10: Pedals, and a mounted gear that was set to automatic.

memory. This was able to run the simulation with the XTAL headset, with an average of 70 FPS.

Headphones A wireless Bluetooth headset was used to provide audio feedback.

Game Engine The simulation environment was made with the Unity Version 2019 (LTS). The car physics were calculated by a third-party software, called Carsim, provided by Mechanical Simulation (Corporation 2020). This physics engine outputs telemetry data with an accuracy of research quality.

Chapter 4

Results

4.1 Introduction

About 157 students were asked to participate in the research project. Of these, 13 students completed all mandatory activities. 2 of these represent group 1 (G1), as they only were able to complete the course in VR, while the remaining 11 students were assigned to group 2 (G2). Originally, the intention was to evenly distribute all candidates among the two groups. Unfortunately, the simulator was not ready in time for testing before the legal period to conduct night driving training ended.

4.2 Disclaimer

I would like to make a disclaimer, as these results are not meant to put Way's traditional teaching approach, or their simulators, in a bad light. The purpose of the comparison was to test an experimental VR simulator provided by Way, to see whether it produced a learning outcome that was non-inferior to their traditional teaching approach.

4.3 Test results

The test candidates were N = 16, because there were 3 dropouts. Final data presented was for N = 13, divided by N = 5 men, and N = 8 women. Figure 4.4 shows the gender distribution. The age range for men varied from 16-33 years, and 15-21 years for women. G1 and G2 was used in a crossover to act as controls for each other. The intention was to use G1 to present the evaluation of the VR's feasibility, and to compare the net total of learning outcome from G1 and G2 after conducting both courses. The results were shown in percentages, and it was decided to calculate a *difference* for each statement, before and after completing a course, showed in the right-most column as "Diff.". The tables were made to give a more detailed view over which learning goals the VR simulator proved non-inferior. The difference was calculated by subtracting the test subject's ex-

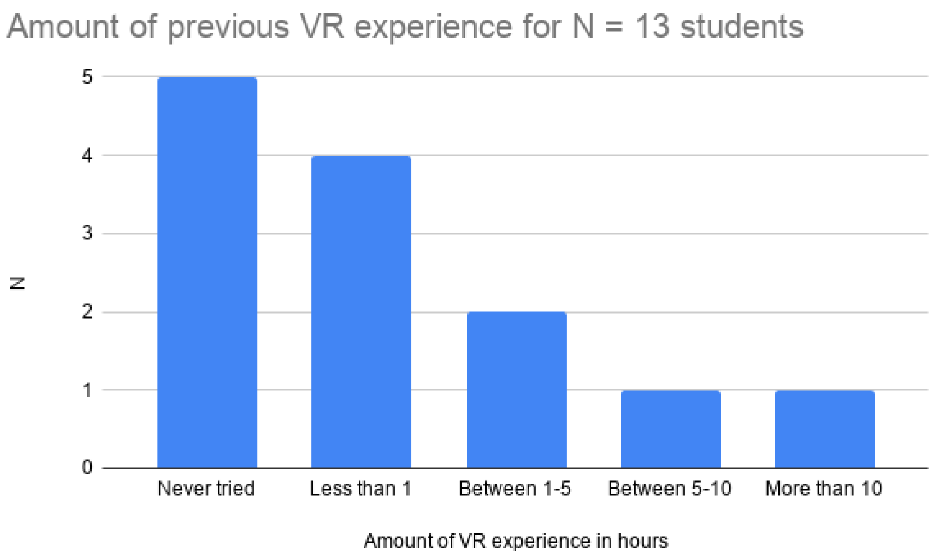

Figure 4.1: An overview of past experience with VR shown in hours. The majority of candidates had little or no experience with VR technology.

pectations from their subjective assessment. For instance, if 90% agreed that they would expect to learn about statement X, and 100% agreed that they actually learned about statement X after completing the course, it would mean a positive difference of 10%. This would be opposite for statements that were outside the night driving course curriculum. Statements outside the curriculum were included to ensure data integrity, and were meant to see whether the test subjects paid attention while answering the questionnaires, or were merely guessing. All tables were translated to English, but the original, Norwegian version was included in Appendix J, due to the risk of misconception when translating. Finally, the test results were presented through mean, and standard deviation values.

4.3.1 Past VR experience

The test subjects' age, gender, past experience, and the type of experience in VR was collected to help consider potential cases of motion sickness from the simulator, as these were possible factors to trigger SS based on suggestions from related research. Past VR experience measured in hours is shown in Figure 4.1, and the different experience types are shown in Figure 4.2. Notice how 72,8% of the past VR experience was from entertainment, shown with blue colours. The majority of candidates had no or little experience with VR. Figure 4.3 shows the age of all participants. The majority of candidates were between 15-16 years old. For N = 13, the mean value was approximately 17 years old, with the standard deviation of approx. 9 years. Figure 4.3 shows that the majority of candidates were women.

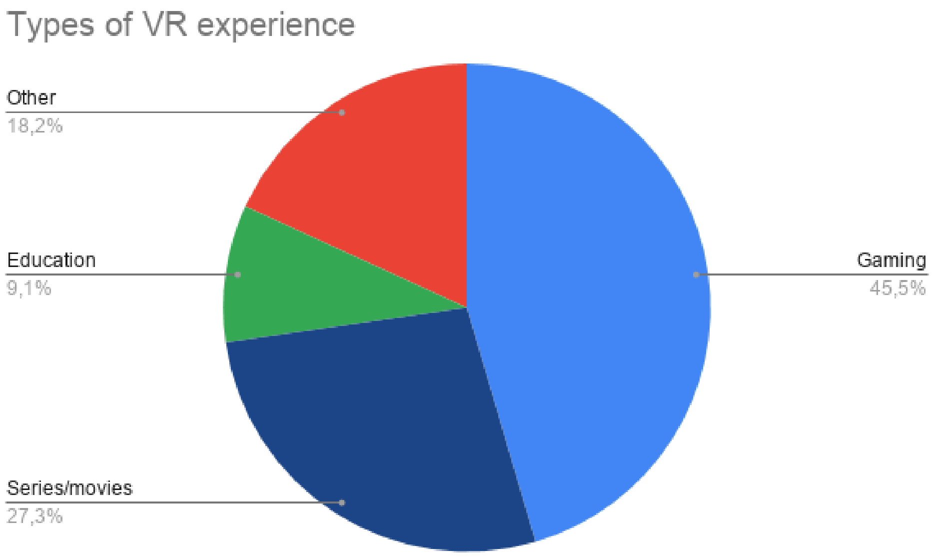

Figure 4.2: An overview of the different types of VR experiences. The majority of experiences came from entertainment from series, movies or gaming.

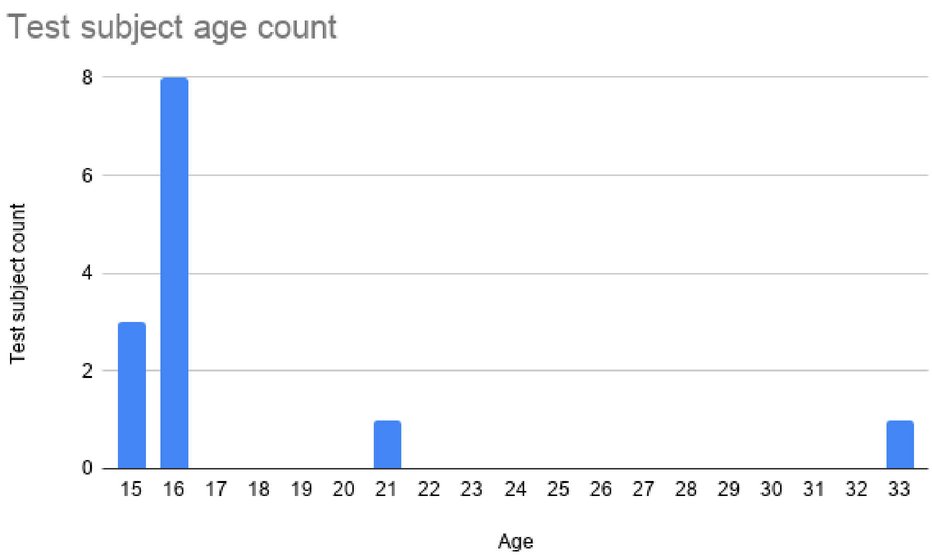

Figure 4.3: An overview of the candidates' age. The majority of candidates were between 15-16 years old, the oldest was 33 years old.

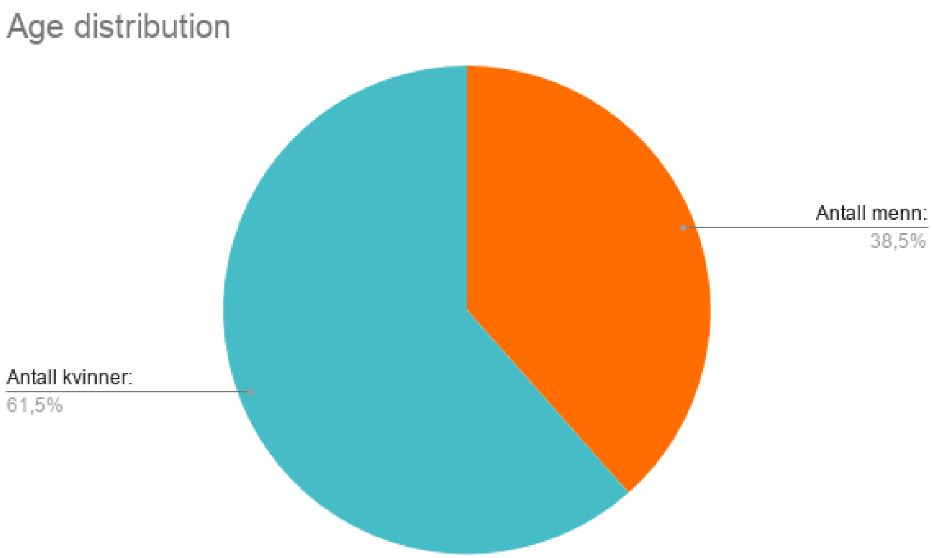

Figure 4.4: An overview of the candidates' gender distribution. The majority of the candidates were women.

4.3.2 Change in traffic awareness and attitude

Table 4.1: The table shows how the traffic awareness for group 1 was influenced by the VR course. The VR course did not negatively influence their awareness in any statement.

Group 1 (VR)	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
I use retroreflectors in lit areas	50%	0%	50%	0%	0%	100%	**50%**
I look both ways before crossing the road in the dark	0%	0%	100%	0%	0%	100%	**0%**
Retroreflectors have an expiration date	50%	0%	50%	0%	50%	50%	**50%**

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Table 4.1 – *Continued from previous page*

Group 1 (VR)	Before driving			After driving			
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
I look both ways before crossing the road if the area is lit	0%	0%	100%	0%	0%	100%	**0%**
I use a retroreflectors when it is dark	0%	0%	100%	0%	0%	100%	**0%**
These statements are positive if they disagree.							**Positive if <= 0%**
Cars can see me, if their front beam hits me	0%	0%	100%	50%	50%	0%	**-100%**
Cars can see me in lit areas	0%	0%	100%	0%	100%	0%	**-100%**
Most pedestrian accidents happens in the dark	0%	50%	50%	0%	50%	50%	**0%**

Table 4.1 shows whether the VR course influenced G1's awareness and attitude in traffic, in a positive way. The results were promising for the VR course, as it did not negatively influence their awareness in any statement. Although, their opinion did not change 4 statements, it was due to the fact that it was known beforehand. This was why a 0% change was considered positive, as there were cases where they already possessed the knowledge. On the other hand, it was positive that their traffic awareness improved in 4 statements.

Table 4.2: The table shows how the traffic awareness for subjects in G2 was influenced by the traditional course. In 6 of 8 statements, the RL course positively influenced their traffic awareness.

Group 2 (RL)	Before driving			After driving			Positive if >= 0%
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
I use retroreflectors in lit areas	45,4%	27,3%	27,3%	9,1%	27,3%	63,6%	**36,3%**

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Table 4.2 – *Continued from previous page*

Group 2 (RL)	**Before driving**			**After driving**			
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
I look both ways before crossing the road in the dark	0%	0%	100%	0%	0%	100%	**0%**
Retroreflectors have an expiration date	18,2%	0%	81,8%	9,1%	0%	90,9%	**9,1%**
I look both ways before crossing the road in if the area is lit	0%	0%	100%	0%	0%	100%	**0%**
I use a retroreflectors when it is dark	27,3%	27,3%	45,4%	0%	9,1%	90,9%	**45,5%**
These statements are positive if they disagree.							**Positive if <= 0%**
Cars can see me, if their front beam hits me	18,2%	54,5%	27,3%	27,3%	27,3%	45,4%	**18,1%**
Cars can see me in lit areas	0%	54,5%	45,5%	0%	54,5%	45,5%	**0%**
Most pedestrian accidents happens in the dark	9,1%	9,1%	81,8%	9,1%	0%	90,9%	**9,1%**

Table 4.2 shows that G2's traffic awareness was influenced positively for 6 out of 8 statements. Here, their opinion remained unchanged in 2 statements, because these were known from before. Their opinion was unchanged for the statement "Cars can see me in lit areas", which was unwanted, as they were supposed to learn that they are not necessarily visible in lit areas. However, the formulation was somewhat vague, which allowed different interpretations.

Table 4.3: The table shows how G2's traffic awareness were positively influenced in all statements after completing the VR course.

Group 2 (VR)	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
I use retroreflectors in lit areas	36,4%	36,4%	27,2%	9,1%	0%	90,9%	**62,8%**
I look both ways before crossing the road in the dark	0%	0%	100%	0%	0%	100%	**0%**
Retroreflectors have an expiration date	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
I look both ways before crossing the road if the area is lit	0%	0%	100%	0%	0%	100%	**0%**
I use a retroreflectors when it is dark	9,1%	36,4%	54,5%	0%	0%	100%	**45,5%**
These statements are positive if they disagree.							**Positive if <= 0%**
Cars can see me, if their front beam hits me	27,3%	54,5%	18,2%	36,4%	45,4%	18,2%	**-9,1%**
Cars can see me in lit areas	9,2%	45,4%	45,4%	0%	81,8%	18,2%	**-18,2%**
Most pedestrian accidents happens in the dark	18,2%	9,1%	72,7%	27,3%	18,2%	54,5%	**-18,2%**

Table 4.3 shows how the G2's traffic awareness were influenced after completing the VR course. At this point, the group had completed the same course in RL and in VR. The results were positive for all statements, in which, 3 statements were unchanged.

On an interesting note, the questionnaire for RL and VR were designed to see if the outcome measured by G2's post-RL-Q was equal to their expectations before driving the VR course. For example, the statement "Most pedestrian accidents happens in the dark" in Table 4.2 showed that 9,1% disagree, 0% somewhat agree and 90,9% agree. It was anticipated that this would be equal to their expectations to the VR course. Instead, by looking at the same statement in Table 4.3, their opinion changed to 18,2% disagree, 9,1% somewhat agree, and 72,7% agree. This means that there were other factors, which influenced the learning process. This was taken into the consideration when evaluating the uncertainty in the data. However, this thesis did not address these factors, because they were outside of this thesis' scope. Although, this emphasised the reason to include pre-Qs to help avoid such anomalies.

4.3.3 Evaluation of the simulator application

Table 4.4: The table shows the subjects' opinion on simulators when applied in the driving education. The majority of candidates had a positive view on this as a learning tool.

Statement	**Disagree**	**Slighty agree**	**Agree**
I think it is better to complete the course inside	15,4%	46,2%	38,4%
I would rather complete the course inside if I could	15,4%	23,1%	61,5%
The course were exciting	0%	0%	100%
It was always easy to understand what was happening	7,7%	30,8%	61,5%
I believe that this can be used to complete the course throughout the year	7,7%	30,8%	61,5%
If possible, I would rather completed the course closer to the driving exam where I could drive myself	15,4%	38,5%	46,1%
I think driving in pairs is a good solution	23,1%	23,1%	53,8%
I think the simulator went through the learning goals too quickly	69,2%	7,7%	23,1%

Table 4.4 shows opinions about the simulators in general, compared to the traditional night driving course. This was included to address the *will to use* simulators, to help consider the learning tool for commercial use, or to motivate further research. Moving from top to bottom through the statements: 1 & 2) The majority of candidates would rather conduct the night driving course inside, if it were possible. 3) The course were unanimous seen as exciting. 4) The majority thought it was easy to understand what was happening in the simulator. 5) The majority thought the simulator can be used all around the year. 6) The majority would

rather complete the course closer to the driving exam, where they could drive themselves. 7) The majority thought that driving together with another student was a good solution. 8) The majority did not think that the simulator went through the learning goals too quickly.

By the assumption that the night driving course can only be conducted outside, except when in a simulator, statement 1) & 2) from the results show that the students would rather complete the course in a simulator. From a learning aspect, it was positive that most students agreed to statement 4). Chapter 2 mentions the simulator's availability all year, which was supported by the majority in statement 5). Statement 6) suggested it would be too early to complete the night driving course, as the majority of candidates were under the legal age of 16 when they took the basic traffic course. This was not a problem in a simulator-based approach, as there was no legal age for driving in a simulator. On another note, students were traditionally driving in pairs at Way traffic school, and it seemed that the majority were satisfied with this based on statement 7). If the student-pair solution proved to be of interest, maybe the VR simulator could be redesigned to fit two students concurrently, as the current solution only supports one student at a time. According to statement 8), the minority of students disagreed that the simulator went too quickly through the learning goals. Conclusively, the subjects gave positive feedback, which emphasised the availability, legal challenges, and reasonable learning tempo.

4.3.4 Evaluation of the night driving course

The tables 4.5, 4.7, 4.6 presents the subjective evaluation of each course for G1, G2 after VR, and G2 after the real life course, respectively.

Table 4.5: The subjective evaluation of the VR course for G1. They learned equal to or more than they expected in all listed learning goals.

Group 1 (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
I will learn following statements from the course	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
Receive insight on realistic situation	0%	0%	100%	0%	0%	100%	**0%**
How accidents occur in the dark	0%	0%	100%	0%	0%	100%	**0%**
Risk assessment in the dark, compared to daylight	0%	0%	100%	0%	0%	100%	**0%**

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Table 4.5 – *Continued from previous page*

Group 1 (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
I will learn following statements from the course	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
The use of retroreflectors	0%	0%	100%	0%	0%	100%	**0%**
The use of lights in the dark	0%	0%	100%	0%	0%	100%	**0%**
The difference when using/not using a retroreflectors	0%	50%	50%	0%	0%	100%	**50%**
How the darkness affect the line of sight	0%	50%	50%	0%	0%	100%	**50%**
How you should travel along the road in the dark	0%	0%	100%	0%	0%	100%	**0%**
How the car should be placed	0%	50%	50%	0%	50%	50%	**0%**
What factor speed has in the dark	0%	50%	50%	0%	0%	100%	**50%**
These statements are not a part of the night driving.							**Positive if <= 0%**
The use of warning triangle	0%	0%	100%	0%	100%	0%	**-100%**
How to speed in the dark	50%	50%	0%	50%	50%	0%	**0%**
The use of lights in daylight	0%	100%	0%	50%	50%	0%	**-50%**
Learn about the different lights on the car	0%	0%	100%	0%	50%	50%	**-50%**

Table 4.5 shows how much G1 thought they learned, compared to what they would expect before and after completing the VR course. Their subjective evaluation was positively influenced in all statements. Meaning, they learned equal to or more than they expected in all listed learning goals based on the results, except for the learning goals that were not included in the course.

Table 4.6: The subjective evaluation of the traditional night driving course for G2. They learned more than they expected in 7 out of 14 statements.

Group 2 (RL)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
I will learn following statements from the course	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
Receive insight on realistic situation	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
How accidents occur in the dark	0%	9,1%	90,9%	0%	27,3%	72,7%	**-18,2%**
Risk assessment in the dark, compared to daylight	0%	18,2%	81,8%	0%	9,1%	90,9%	**9,1%**
The use of retroreflectors	0%	9,1%	90,9%	0%	0%	100%	**9,1%**
The use of lights in the dark	0%	18,2%	81,8%	0%	9,1%	90,9%	**9,1%**
The difference when using/not using a retroreflectors	9,1%	0%	90,9%	0%	0%	100%	**9,1%**
How the darkness affect the line of sight	0%	27,3%	72,7%	0%	18,2%	81,8%	**9,1%**
How you should travel along the road in the dark	0%	18,2%	81,8%	9,1%	27,3%	63,6%	**-18,2%**
How the car should be placed	0%	27,3%	72,7%	18,2%	54,5%	27,3%	**-45,4%**
What factor speed has in the dark	0%	9,1%	90,9%	9,1%	18,2%	72,7%	**-18,2%**
These statements are not part of the night driving.							**Positive if <= 0%**
The use of warning triangle	9,1%	18,2%	72,7%	0%	18,2%	81,8%	**9,1%**
How to speed in the dark	27,3%	18,2%	54,5%	45,4%	27,3%	27,3%	**-27,3%**
The use of lights in daylight	9,1%	36,4%	54,5%	18,2%	36,4%	45,4%	**-9,1%**

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Table 4.6 – *Continued from previous page*

Group 2 (RL)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
I will learn following statements from the course	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
Learn about the different lights on the car	0%	36,4%	63,6%	0%	9,1%	90,9%	**27,3%**

Table 4.6 shows how much the G2 thought they learned compared to what they would expect, before and after completing the traditional night driving course. A positive difference was seen for 7 of 14 statements. Meaning, for half of the statements, the students thought they received a learning outcome non-inferior to what they expected.

Table 4.7: The subjective evaluation of the VR course for G2. They learned more than they expected in 10 out of 14 statements.

Group 2 (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
Receive insight on realistic situation	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
How accidents occur in the dark	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
Risk assessment in the dark, compared to daylight	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
The use of retroreflectors	9,1%	18,2%	72,7%	0%	0%	100%	**27,3%**
The use of lights in the dark	0%	9,1%	90,9%	0%	9,1%	90,9%	**0%**
The difference when using/not using a retroreflectors	0%	9,1%	90,9%	0%	0%	100%	**9,1%**
How the darkness affect the line of sight	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
How you should travel along the road in the dark	0%	18,2%	81,8%	0%	27,3%	72,7%	**-9,1%**

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Table 4.7 – *Continued from previous page*

Group 2 (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
How the car should be placed	9,1%	36,4%	54,5%	9,1%	18,2%	72,7%	**18,2%**
What factor speed has in the dark	0%	9,1%	90,9%	0%	18,2%	81,8%	**9,1%**
These statements are not part of the night driving.							**Positive if <= 0%**
The use of warning triangle	9,1%	18,2%	72,7%	9,0%	45,5%	45,5%	**-27,2%**
How to speed in the dark	36,4%	9,1%	54,5%	27,3%	9,1%	63,6%	**9,1%**
The use of lights in daylight	18,2%	54,5%	27,3%	27,3%	45,4%	27,3%	**-9,1%**
Learn about the different lights on the car	0%	9,1%	90,9%	0%	9,1%	90,9%	**0%**

Although, G2 had completed both courses at this point, the Table 4.7 shows the difference between their expectations and subjectively measured learning outcome, with the emphasis on the VR course. The test subjects reported that they learned more than they expected in 10 out of 14 statements. There was a possibility that the expectations were higher after completing the traditional course, and that this would influence the results for G2 when evaluating the VR course. It would have been interesting to see if this would apply for G1 as well, because they would complete both courses in a different order. However, this was not addressed due to the lack of data for G1.

4.3.5 A learning outcome comparison between the VR- and the RL course

Subjective assessment

Table 4.8: The table shows a comparison between the subjective evaluation from each group after completing their first course. The VR course appeared to be non-inferior to the RL course in the majority of statements.

Subjective evaluation	**Net difference for each course**			**Positive for the VR course if >= 0%**	
I will learn following statements from the course	**G1 (VR) Diff.**	**G2 (RL) Diff.**	**G2 (VR) Diff.**	**G1 (VR) learned % more than G2 (RL)**	**G2 (VR) learned % more than G2 (RL)**
Receive insight on realistic situation	0%	-9,1%	-9,1%	**9,1%**	**0%**
How accidents occur in the dark	0%	-18,2%	0%	**18,2%**	**18,2%**
Risk assessment in the dark, compared to daylight	0%	9,1%	-9,1%	**-9,1%**	**-18,2%**
The use of retroreflectors	0%	9,1%	27,3%	**-9,1%**	**18,2%**
The use of lights in the dark	0%	9,1%	0%	**-9,1%**	**-9,1%**
The difference when using/not using a retroreflectors	50%	9,1%	9,1%	**40,9%**	**0%**
How the darkness affect the line of sight	50%	9,1%	0%	**40,9%**	**-9,1%**
How you should travel along the road in the dark	0%	-18,2%	-9,1%	**18,2%**	**9,1%**
How the car should be placed	0%	-45,4%	18,2%	**45,4%**	**63,6%**
What factor speed has in the dark	50%	-18,2%	-9,1%	**68,2%**	**9,1%**
These statements are not part of the night driving.				**positive for the VR course if <= 0%**	
The use of warning triangle	-100%	9,1%	-27,2%	**-109,1%**	**-36,3%**
How to speed in the dark	0%	-27,3%	9,1%	**27,3%**	**36,4%**
The use of lights in daylight	-50%	-9,1%	-9,1%	**-40,9%**	**0%**

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Table 4.8 – *Continued from previous page*

Subjective evaluation	**Net difference for each course**			**Positive for the VR course if >= 0%**	
I will learn following statements from the course	**G1 (VR) Diff.**	**G2 (RL) Diff.**	**G2 (VR) Diff.**	**G1 (VR) - G2 (RL)**	**G2 (VR) - G2 (RL**
Learn about the different lights on the car	-50%	27,3%	0%	**-77,3%**	**-27,3%**

It was intended to compare the difference in learning outcome between G1 (VR) and G1 (RL), with the difference between G2 (RL) and G2 (VR) to evaluate the VR simulators feasibility. However, it was decided to conduct a comparison between the results from G1 (VR) and G2 (RL), and G2 (VR) and G2 (RL), as G1 had only completed the VR course. Table 4.8 shows a comparison between each of the groups' net difference, and compares the results from G1 with G2. The net difference was taken from the last column in the previous tables. G1 (VR)'s net difference was taken from Table 4.5, G2 (RL)'s net difference was taken from Table 4.6, and G2 (VR)'s net difference was taken from Table 4.7.

The fifth column "G1 (VR) learned % more than G2 (RL)" represents the sum by subtracting the net difference from "G1 (VR)" by the net difference from "C2 (RL)". This applied for the sixth column as well. The fifth column showed positive results for the VR course in 10 of the 14 statements compared to the RL course. Excluding statements that were not a part of the curriculum, it was non-inferior in 7 out of 10 learning goals. Moreover, when comparing each group's subjective evaluation of the VR course, showed in the sixth column, it appeared that the VR course was non-inferior in 7 out of 10 learning goals, and 10 out of 14 statements in total. Although, it varied which statements were positive for each comparison.

Objective assessment

An objective assessment consisting of 20 questions were included in both post-Qs. It was decided to round down mean test scores to the closest whole number to show the number of correct answers. G1 had a mean test score of 13 out of 20 maximum points (N = 2, SD = 0,7) after completing the VR course. After G2 completed the RL course, G2 had a mean test score of 13 out of 20 maximum points (N = 11, SD = 2,0). By comparing the mean test score of G1 (VR) and G2 (VR), there was no significant difference in terms of the objective assessment.

G2 received a mean test score of 14 out of 20 maximum points (N = 11, SD = 1,4) after completing the VR course. At this point, G2 had completed both courses, which made it an interesting find to see only a point difference between the mean average of G1 and G2. Although, an increased score was expected, due to the repeated learning factor. In addition, G1's test scores had a lower deviation than G2 after completing the RL course, which means that the amount of correct answers vary more between students after completing the RL course. This makes sense, because the teaching approach was adapted to each student group in the traditional teaching approach, while the simulated course was more predetermined.

4.3.6 Subjective assessment of the RL- and VR approach

Group 1's evalutaion of the VR approach

Table 4.9: The table shows the evaluation of the simulator approach for G1. G1 reported that they were satisfied with the simulator approach.

Did the course manage to teach you..	No	Yes
..the difference between good or bad line of sight?	0%	100%
..the line of sight shown in meters along the road?	0%	100%
..the difference between using/not using a retroreflectors on pedestrians in a good way?	0%	100%
..how the lights on the car should work?	0%	100%
..when oncoming cars uses the wrong lights?	50%	50%
..how lights should be used while driving?	0%	100%
..how the speed should adapt to darkness?	0%	100%
..the car's placement in the dark?	0%	100%
..why meeting accidents occur in the dark?	0%	100%
..how you should act in a safe way in the dark as pedestrian and driver?	0%	100%
..the different risks when you travel in the dark, compared to daylight?	0%	100%

Table 4.9 shows the evaluation of the simulator for G1. They thought the simulator was able to teach them all learning goals mentioned in the table, except "..when oncoming cars uses the wrong lights", where it was a 50/50. Generally, G1 was satisfied with the simulator approach.

Group 2's evaluation of the RL- and VR approach

Table 4.10: The table shows the evaluation of the simulator, and the traditional approach for G2. The simulator approach was non-inferior to the traditional approach for the majority of statements.

Evaluation of the course approach	**Traditional**		**Simulator**		**Positive if >= 0%**
Did the course manage to teach you..	**No**	**Yes**	**No**	**Yes**	**Diff.**
..the difference between good or bad line of sight?	9,1%	90,9%	0%	100%	**9,1%**
..the line of sight shown in meters along the road?	18,2%	81,8%	0%	100%	**18,2%**
..the difference between using/not using a retroreflectors on pedestrians in a good way?	0%	100%	0%	100%	**0%**
..how the lights on the car should work?	9,1%	90,9%	0%	100%	**9,1%**
..when oncoming cars uses the wrong lights?	18,2%	81,8%	18,2%	81,8%	**0%**
..how lights should be used while driving?	9,1%	90,9%	0%	100%	**9,1%**
..how the speed should adapt to darkness?	36,4%	63,6%	9,1%	90,9%	**27,3%**
..the car's placement in the dark?	36,4%	63,6%	9,1%	90,9%	**27,3%**
..why meeting accidents occur in the dark?	27,3%	72,7%	0%	100%	**27,3%**
..how you should act in a safe way in the dark as pedestrian and driver?	18,2%	81,8%	9,1%	90,9%	**9,1%**
..the different risks when you travel in the dark, compared to daylight?	0%	100%	9,1%	90,9%	**-9,1%**

Table 4.10 shows the evaluation of the simulator and the traditional approach for G2. For all statements except "..the different risks when you travel in the dark, compared to daylight?", the VR simulator approach was non-inferior to the traditional course. Furthermore, Table 4.9 shows almost an unanimous "Yes" on all statements. Meaning, the simulator approach covered these learning goals adequately according to the reports. It was positive that the simulator was non-inferior as a teaching approach, compared to the evaluation given by G2 of the traditional approach.

4.3.7 Evaluation of VR as a learning tool

Table 4.11: Opinion on VR simulator as a learning tool among all test subjects. The simulator was considered as a good learning tool, based on the majority of statements.

All	Before driving			After driving			Positive if >= 0%
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
You can learn more from the night driving course in a VR simulator than by traditional methods.	30,8%	46,2%	23,0%	15,4%	38,4%	46,2%	**23,2%**
I think the simulator is realistic.	0%	46,2%	53,8%	0%	23,1%	76,9%	**23,1%**
The VR simulator can replace parts of the mandatory driving training.	23%	38,5%	38,5%	7,7%	38,5%	53,8%	**15,3%**
VR should replace all mandatory driving training.	61,5%	23,1%	15,4%	61,6%	30,7%	7,7%	**-7,7%**
I learn more from a VR simulator, as it provides a better overview of my surroundings.	15,4%	30,8%	53,8%	15,4%	61,5%	23,1%	**-30,7%**
The virtual world in the simulator was immersive.	0%	30,8%	69,2%	7,7%	23,1%	69,2%	**-7,7%**
I think the experienced speed was equivalent to the virtual speedometer.	15,4%	30,8%	53,8%	7,7%	38,5%	53,8%	**7,7%**
The simulator made me think I sat in a real car.	15,4%	30,8%	53,8%	7,7%	30,8%	61,5%	**7,7%**

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Table 4.11 – *Continued from previous page*

All	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Disagree**	**Slighty agree**	**Agree**	**Disagree**	**Slighty agree**	**Agree**	**Diff.**
It was more fun to drive in a simulator instead of participating in the traditional night driving demonstration.	7,8%	46,1%	46,1%	0%	46,1%	53,9%	**7,8%**
These statements are positive if they disagree.							**Positive if <= 0%**
The VR technology has not future in the driving education.	92,3%	0%	7,7%	92,3%	0%	7,7%	**0%**
The VR simulator does not give more learning outcome compared to other car simulators.	15,4%	53,5%	30,1%	61,6%	30,7%	7,7%	**-46,2%**
The simulator was uncomfortable to use.	61,5%	38,5%	0%	76,9%	15,4%	7,7%	**-7,7%**

Table 4.11 shows the results from the subjects' opinion towards VR as a learning tool. This proves positive for 10 out of 12 statements. It was expected that a VR headset would offer a better overview over their surroundings, which allowed them to learn more while driving. However, this was not the case. Instead, there was a -30,7% change after testing the simulator. Although, the majority did not disagree with this statement, there could be technological restrictions, that lead to this result. After testing the VR simulator, 15,3% of students were more agreeable to replace parts of the mandatory driving training with a simulator. On the other hand, after testing the VR simulator, 7,7% were *less* interested to replace all mandatory activities. Based on these results, the students were positive to the idea of replacing the night driving course with a simulator, but they thought it was still too early to consider replacing more at the moment.

4.3.8 Feedback on simulator sickness

Table 4.12: The table shows reported symptoms related to SS. No cases of SS was reported.

Which symptoms occurred under- or after the simulator experience?	No	Yes
Dizziness	100%	0%
Headache	100%	0%
Vomiting	100%	0%
Nausea	100%	0%
Cold sweat	100%	0%
Eye strain	100%	0%
Extra tiredness	100%	0%
Other	100%	0%

No candidates reported any symptoms regarding SS. The Table 4.12 shows a list of potential symptoms that were measured in the test case. This means that driving in 40 minutes with this solution did not trigger cases of SS. Other possible risk-reducing factors are discussed in Chapter 5.

4.4 Limitations to the research

4.4.1 Adaptation of the learning approach

The night driving course consisted of a practical demonstration, which was adapted by the traffic teachers depending on the student group. The students had different prerequisites and experience beforehand, which forced the teachers to adapt the learning approach. Meaning, there was no standard learning approach that was used for every night driving demonstration, even when using the same learning plan. Therefore, the data collected from the RL courses did only represent the learning approaches conducted in Spring 2021. On the other hand, the adaptation creates the desired diversity of test candidates, and emphasises why expectations should be collected when measuring the learning outcome from a course, where the teaching approach varies.

As G1 had lower deviation compared to G2, there exists an uncertainty to the data, which has to be taken into account, as $N = 2$ for G1.

4.4.2 Technical difficulties

The simulated night driving course at Way consisted of two parts, but due to the VR setup's shortcomings, the students were only able to test part one. Meaning, the VR simulation only covered about half of the course's content. This influenced the objective assessment in the test results, as half of the course was excluded from G1. Thus, it was expected that the test score would be lower in G1, compared to those who participated in the traditional night driving course that covered all learning goals.

4.4.3 Errors in the questionnaires

While analysing the results, errors were found, which I want to address:

The post-questionnaires were missing the question "How to perceive pedestrians in the dark", which was why these results were not presented in the Table 4.7, Table 4.5, Table 4.6, and Table 4.8.

In the post-VR questionnaire, the question "VR can replace parts or all mandatory driving training" was repeated twice. Therefore, it was decided to exclude the duplicate question. Unfortunately, there was a spelling error, as it was intended to say something similar to "..replacing the night driving course with a VR simulator" in the pre-VR and post-VR questionnaires. The existing formulation was more vague, because it addressed "parts of the driving training", and not "the night driving course", specifically.

Although, I did a mistake here, the statement was assumed to include the dark driving course, as "all mandatory driving training" cannot be completed in a simulator anyway. Either way, it only shows the public opinion on replacing parts of the mandatory activities, which does not exclude the night driving course.

Chapter 5

Discussion

5.1 RQ1

Section 2.2.4 lists possible benefits, which shows recent motivation in research to utilise simulators for driving training. In addition, it describes how VR technology is more mobile, and cheaper compared to high fidelity simulators. However, VR simulators face potential challenges as well, which need to be addressed before they are considered learning tools for the mandatory driving training. Although, there exist many potential challenges, advantages, and finds, it was decided to include the most relevant aspects to answer **RQ1**.

Norway's motivation to apply driving simulators as a learning tool in the mandatory driving training

Driving schools were in the early phase of implementing driving training simulators (DTS) into the mandatory driving education in Norway. Way traffic school is one of the few traffic schools in Norway that focused on simulator-based teaching to help students with their driving training (Amdahl 2020). Although, the public road regulations did not allow any of the mandatory driving training to be replaced by a simulator. Instead, traffic schools were responsible for their own teaching approach beyond the mandatory activities, and the NPRA did not require a minimum amount of driving hours to participate in the driving exam (Vegdirektoratet 2016). This made it possible for a traffic schools to use their available resources to support the students' learning process.

Section 2.5.3 describes different simulator applications in Norway. This shows Norway's motivation for simulator-based driving training. However, there were legal challenges, and technological restrictions, which prevents simulators to replace mandatory driving training. On the other hand, simulators were already accepted as a part of the driver's education in other countries, such as the Netherlands (SWOV 2020), the UK, Finland (Sætren, Lindheim *et al.* 2019, p. 1669), and New Zealand (driving 2021). Recent research also shows an interest in Canada

(Hirsch and Bellavance 2016a) as well. Assuming technology improves over time, how long will it take before technology overcomes these challenges in Norway as well? The focus was on the legal challenges in Norway that were due to technological restrictions. If a VR simulator satisfied these requirements, it would be ready to conduct mandatory driving training.

Possible requirements for a VR simulator as a learning tool

For a simulator to be approved by the NPRA for driving training, the simulator had to give a certain amount of learning outcome, which must be non-inferior to the standard, traditional approach (Amdahl 2020). According to (Hirsch and Bellavance 2016b, p. 79), it had to offer a minimum 180° FOV to be sufficient for training the majority of driving skills, particularly skills associated with reducing the risk of involvement in intersection crashes. Furthermore, the study (SWOV 2020, p. 3-4) suggested that a simulator must be a good imitation to ensure optimal learning effect. The results showed that all driver learners experienced the simulator as realistic. On the other hand, about 30% of the candidates did not think that they would learn more from the simulator, as it provided a better overview of their surroundings. This was not expected, because it was believed that the VR HMD improved this aspect. Even so, the majority slightly agreed, which could be because they thought it was of equal quality.

In addition to the quality of the simulator, the course quality must be considered as well (SWOV 2020, p. 3-4). If a simulator or its simulation was of poor quality, it would impact the student's ability to learn. Table 4.9 and Table 4.10 lists learning goals for the night driving course. According to the majority of driver learners, the simulation-based teaching approach was non-inferior to the traditional approach, in terms of covering the learning goals. This means that the current design, made the simulator's educational impact optimal.

As previously mentioned, the traditional night driving course conducted at Way was adapted based on the student group. Therefore, the quality of the teaching approach depended on the driving instructor's competence, and skills to adapt the course correspondingly. This was not the case for an instructor-free simulator approach that was designed to guide the student through a deterministic path with checkpoints. Offering a lesson at each checkpoint, allowed the student to observe, experiment, and digest each lesson in their own tempo. Based on the results, more was learned from a checkpoint-based learning approach. Furthermore, the objective assessment showed more deviation in the test scores from the RL course than the VR course. Meaning, a more deterministic course structure results in a more consistent test score.

Potential risks regarding the simulator-based learning approach

The statement "How to speed in the dark" in Table 4.7 was increased by 9,1%, which was unwanted. Although, this number was arguably low, it raised the question whether the simulator approach motivated students to drive faster in the dark. There are multiple reasons for this. For instance, a simulator offered the lack of responsibility compared to the real life course, as a crash would not result in damaged properties, or in worst case, death. This was also connected to a young target group, as it was assumed to be known that traffic accidents occurred more often for inexperienced drivers. With the goal of safe driving, results showed a simulator concern, which must be prevented to discourage students to drive fast in the dark.

The VR simulator received positive feedback from the driver learners. Over 84% would rather complete the night driving course inside, and over 92% thought it could be used to complete the course throughout the year. Although, students thought the course was exciting in VR, over 76% of students preferred driving in pairs, which they were able to in the traditional approach. The current solution limits such teaching options, which raised another concern: the possibility that a simulator-based approach restricts other teaching methods as well. Whether teaching methods are restricted or not, depends on the solution. For example, the simulator can be designed to consist of two connected setups, to support pair driving. Its smaller size compared to high fidelity simulators, offered the opportunity to form a classroom with multiple setups. This allowed driving instructors to teach multiple students concurrently. Therefore, the teaching methods were not restricted by a simulator-based approach, but depends on the course design.

On the other note, the new tools offered the opportunity to design a computerised assessment and logging, which removed the subjective clinical assessment from the driving teacher (Engen 2008, p. 126). This would be a step towards a standardised driving education, which would be of interest for the public sector. However, a standardised design raises a concern, where the course format becomes a possible hindrance for learning, as some students learn more quickly than others. However, the checkpoint based course that was designed by Way, allowed students to learn in their own pace, thus, showed an example on how to avoid this concern.

Issue with the retention of knowledge

The study (Hirsch and Bellavance 2016a, p. 65) described some concerns if a simulator was to be used as an educational tool. It used (Parkes 2005, p. 6) as reference, which suggested three elements that had to be addressed: 1) The efficiency and acceptability of the learning in the simulator, 2) The transfer of the learning to the real world, and 3) The retention of skills or knowledge learned. In this thesis, user acceptance had been measured by the questionnaires, which is shown in Chapter 4. Although, the majority of driver learners thought that a simulator could not replace all parts of the mandatory driving education, they were willing to conduct parts of the mandatory driving training in a simulator. Based on their answers, the simulator thought them efficiently compared to traditional teaching. As for the transfer process, it had been addressed through an objective assessment of the driver learner's change of traffic awareness in the questionnaires. The simulator appeared to influence their traffic awareness positively for the majority of driver learners. However, the retention of skills or knowledge learned, required a measurement of the students driving skills when on the road. This was not covered by the thesis, which made it difficult to address this concern. If future research were to consider this aspect for the night driving course, It was recommended to look at the methodology suggested by (Hirsch and Bellavance 2016a, p.). Although, instead of general traffic records, perhaps there would be relevant cases for night driving.

Issue with the ability to transfer the knowledge from simulator to on-road

User bias is another challenge, which impacted the simulator's usefulness, and the learning outcome. For example, when a driver learner trained in hazardous situations virtually, and they were aware about driving in a simulator, there was a risk that they would adapt to the simulation by learning the simulator's weaknesses and limitations. A crash in the simulator would not be lethal, and this fact may influence their mindset to sense danger, because they were free from responsibilities. There was also a risk, where their attitude learned in the simulator posed a threat on the road, as there was no retry element in reality. Although, it seemed challenging to design a solution that completely removes their knowing about the environment being simulated. Even so, providing a good imitation is crucial to the transfer of learning outcome (SWOV 2020, p. 3). Ideally, there would be minimal difference between the virtual- and the real world, from a learning perspective, to ensure optimal transfer of learning outcome (Hirsch and Bellavance 2016a, p. 65). Thus, the simulation must have a good imitation of the reality to avoid issues with the transfer from the simulation to a on-road environment.

Risk of simulator sickness

For a VR simulator to be utilised as a part of the teaching process, there must be applied certain preventative measures to reduce the risk of SS, as it was reported by past research to be a major issue. Therefore, preventative measures must be implemented in both hardware and software. For example, if the latency exceeded a noticeable limit, a sensory mismatch may occur, which will most likely trigger SS. A study from MIT (Trafton 2014) suggested that latency was noticed down to 13ms. This means, the higher the latency was above this threshold, the more noticeable the latency became, which increased the risk of SS. Furthermore, design challenges regarding FPS, and visual quality must be solved to avoid neural mismatch as well. As for hardware, the computer that runs the simulation must have the necessary graphical hardware to provide the optimal performance. There must also be a minimal difference in latency between the motion system, and the visual graphics.

Simulator setup aside, the risk of SS can be reduced through the teaching process as well. For example, let students adapt to the simulator before they start with the driving lessons. This approach was used by Way in their CAVE simulators to prevent or reduce the risk of SS for students who were new to simulators, or quickly became ill. Introducing easier tasks, such as keeping a certain speed limit on a straight path, or turning in a large-radius corner, made it easier for the students to adapt to the simulator. When the students felt more comfortable in the simulator, the students were introduced to more advanced tasks and traffic scenarios. As a result, there were rare cases of SS, and these were usually because the driver learner was more prone to car sickness (Amdahl 2020). Thus, steps in the teaching process was made to reduce the the risk of SS.

Simulators viability and economic gain depends on user acceptance

The study (Sætren, Birkeland *et al.* 2019, p. 3) suggested a risk where a student was unwilling to use a simulator, if the simulator-based approach was instructor-free. To maintain the user acceptance, the simulator can be designed according to the technology acceptance model. It must be perceived as useful, and easy to use, which results in its intention to be used, as shown in Figure 2.8. Besides, simulator lessons conducted at Way were not instructor-free. Instead, the driving instructor often monitored the driver learners from a base station. This approach was reported to be popular among driving students (Amdahl 2020), thus, removed this concern.

Simulators are too costly compared to what they can offer

A VR simulator included a VR headset with a cost of 50 000 NOK, which was almost 10 times more than the price of an average VR headset. However, there were concerns regarding performance and quality of the driving experience. The XTAL headset provided a 5K resolution for both eyes in their central vision. In addition, it offered a resolution adjustment based on built-in eye tracking, which reduced the quality in the peripheral vision close to 40% of the maximum resolution to save computer resources while maintaining the 5K resolution for the central vision. Based on feedback from multiple test subjects, XTAL offered a resolution that was insufficient. For instance, it was reported that signs were difficult to read from a distance, especially if they were myopic. This affected their overall vision experience while driving. These technological limits was reported in the study (Ihemedu-Steinke, Sirim *et al.* 2015, p. 498-499) as well, and was seen as one of the elements that negatively influenced the transfer process suggested by (SWOV 2020, p. 3).

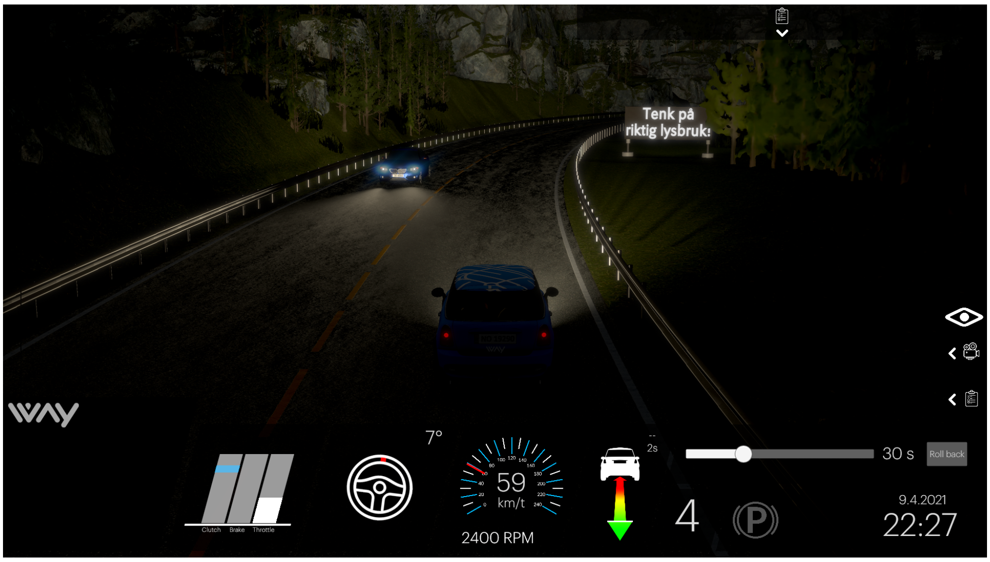

Figure 5.1: Way's CAVE simulator utilised full visual assets, which included moving cars and pedestrians.

5.2 RQ2

Simulator sickness was one of the main challenges when utilising a VR simulator for driving training. How had the VR simulator, which included a motion system, influenced the probability of SS? To answer this, it was decided to compare existing research with the test results in the light of SS theories, which are presented in Section 2.4.2.

Among the test subjects, only 2 candidates were older than 16, with 33 years as the oldest. The studies (Ihemedu-Steinke, Rangelova *et al.* 2017, p. 7) and (Brooks *et al.* 2010, p. 788-796) suggested that those of older age were more prone to SS than those of younger age. This was supported by the neural theory, because those of younger age had less experience. This was supported by the study (SWOV 2020, p. 3-4), which suggested that experienced drivers were more prone to SS than inexperienced drivers. This would explain one of the reasons for why the majority of candidates were not reporting any symptoms. Moreover, the study (Ihemedu-Steinke, Sirim *et al.* 2015, p. 498) reported a higher occurrence for women, than for men. Although, with 5 men and 8 women, no significant difference were found in this study. Besides, the study (Park *et al.* 2020, abstract) conducted an older driver assessment study, and did not find any age or gender effects either.

Furthermore, the study (Ihemedu-Steinke, Rangelova *et al.* 2017) reported more cases of SS with full VA, than when it used limited VA. It appeared to be less neural mismatch, if the virtual environment looked more realistic. For example, their results for number of cases for eye strain was 14% for N = 36. However, there were no reported cases of any SS symptom in this test case. Keep in mind that, due to the size of the test sample, the risk of SS symptoms covered by the post-VR questionnaires had an uncertainty between 0% and 100%/13 candidates = 7,7% chance per candidate to trigger SS with the current testing tools. Even so, at the most uncertainty, it was still reduced to half of the amount that was reported in the existing study.

The sensory and the postural instability theories were based on the mismatch between the perceived motion, and the experienced motion. A motion system provided physical feedback, which allowed the driver learner to experience the perceived motion. The accuracy of this motion depended on the motion system and the physics calculations. In this setup, the physics engine was of research quality, and the motion system was configured to receive input before the game engine's graphical rendering cycle to avoid latency between the motion, and the simulation. Although, there may exist other possible risk-reducing factors, the motion system reduced the sensory- and the postural instability mismatch, which caused disorientation and nausea, thus, reduced the risk of SS.

5.3 RQ3

To address this research question, it was decided to measure the test subjects' traffic awareness and learning outcome, in terms of subjective- and objective assessment. An experimental, mid-level VR simulator was used to conduct the night driving course simulation for this comparison study between a simulator-based- and traditional learning approach. Section 3.3 describes the setup in more detail. Section 5.1 discusses how a VR simulator was a much cheaper alternative, compared to high fidelity simulators. However, the price reduction was a weak argument, unless the learning outcome was non-inferior to the traditional approach.

Test results showed a positive influence to group 1's traffic awareness, which was non-inferior to their expectations in all learning goals, shown in Table 4.1. This was only the case in 6 out of 8 statements for G2 after they completed the RL course, which was shown in Table 4.2. Even so, all statements were positively influenced compared to their expectations after completing the VR course. This means, students were more likely to change their awareness and attitude in traffic if they conducted the night driving course in a VR simulator.

Table 4.8 provided an overview of a comparison between the test subjects' subjective assessments. Here, the G1 learned more from the VR course than G2 did from the RL course in 7 out of 10 learning goals. This was also the case for G2, when comparing their subjective evaluation of both courses. Although, the VR course was not non-inferior in all statements, it was most likely due to the fact that the simulation only included the first part of the night driving course. Despite this, being non-inferior in the majority of statements was promising for the VR simulator.

Based on results presented in Table 4.10, the simulator was capable of providing the necessary learning to cover all learning goals, according to the G1. G2's take on this is presented in Table 4.9. According to them, the traditional course covered all learning goals, based on the majority. However, their opinion increased in 8 learning goals after completing the VR. The lack of data from G1 made it difficult to say if this effect was due to the repeated learning factor or the VR course. Collectively, more test subjects thought the simulator managed to teach them more than the traditional approach.

Solely, the subjective assessment was not sufficient to evaluate the overall learning outcome, which was why it was decided to include an objective assessment as well. There was no significant difference in the test scores between the VR- and the RL course. Furthermore, it was only a point difference for G2, when comparing their test results after each course. Meaning, it was a 5% increase in their test score after completing both courses, which was considered to be no significant difference. If the VR course included both parts of the night driving course, it would not be unlikely that the test scores would increase by at least 5%. If the test scores were to increase by this amount, it would mean that the students learned more from the VR course than the RL course. Thus, assuming that each course used the same learning plan, the learning outcome acquired from the VR simulator will be non-inferior to the traditional approach, based on the objective assessment.

5.4 Implications and further research

The headset did not provide the required resolution, and future research should consider headsets with increased resolution, or apply necessary measures to make signs readable from a distance. To support future research, the Pimax's VR headset (PRNewswire 2017) is suggested, as it offered an 8K resolution. I can only assume that the performance of VR headsets will continue in that direction, due to the rapid technological advancements. Another challenge, will be to acquire the necessary computer power to run this, as a RTX 3090 graphic card was needed to run the simulation with the XTAL headset in at least 70 FPS.

The testing tools in this thesis was in an experimental phase, and because of its incomplete state, only part one of the night driving course was conducted in the test case. Its shortcomings influenced the accuracy and validity of the results, and the driving experience in general.

5.4.1 Methodological implications

A supplementary survey study was chosen through an informative choice to answer the main problem. Although, other methods have been considered, they were not included in this thesis.

Field studies such as ethnography was not chosen, as it was not relevant to understand what the culture were doing. The interview methodology would be relevant if the study required a more qualitative approach, but a contextual inquiry were not chosen, as it was not important what people did in their real-world context. Finally, deployment studies were considered, as it included providing potential end users with novel technology, such as VR. However, how they would use this technology in their context was not included, because the simulator applications were already used commercially by Way.

On the other hand, self reporting studies, which included interviews, questionnaires and surveys, were considered to be more relevant for data collection. The survey- and questionnaire approach was already discussed in Chapter 3, as they were chosen in this thesis. Although, both single- and group interviews would be relevant in a mixed method approach for this thesis, it was decided to not conduct interviews due to the uncertain circumstances around COVID-19.

The VR simulator offered the environment to conduct laboratory tests, which included highly controlled observations and measurements to answer very specific questions i.e., hypothesis testing. Although, the test subjects were supposed to complete the night driving course independently, controlled observations were relevant to conduct measurements of potential SS symptoms. However, SS was not the main focus of this thesis. Usability testing was considered, but was not chosen, because the simulator was designed to imitate the controls of a real car. A usability test would mean to evaluate the standard layout in most cars, which was not relevant to answer the main problem.

As an interaction designer, I would like to conduct an small interface inspection of the VR simulator to share some of my insights, with the purpose to help Way to improve their simulator, and to demonstrate my skills as an interaction designer. This will only be a minor analysis against a handful of interaction design principles, as it is not the main focus of the thesis, see Section 5.5.

5.4.2 Retrospect

Although I am satisfied with many aspects of this thesis, I learned that there are some aspects I would do differently in retrospect, if I were to write this thesis again.

Firstly, administrative work, such as communicating questionnaires to students, sending approval contracts, and managing simulator testing appointments were much more time consuming than I imagined. This made me realise that I have to estimate more time for this sort of work in future projects. Additionally, I found it difficult to use e-mail as a way to communicate the questionnaires to the minors, as this seemed unfamiliar for the majority. This made the follow-up process for the questionnaires more demanding than anticipated. I quickly learned that I had to use texting as my primary communication channel to follow-up the students, as they were more familiar with this. This made it easier to follow-up the questionnaires that was sent over mail.

There were uncertainties related to the global pandemic, which affected the methodology decision. For example, I found it difficult to make plans for the research project, in terms of data collection, due to the unpredictable circumstances in the local situation. Fortunately, the situation in Trondheim ended up better than anticipated, which made it possible to conduct single interviews. Of course, this was not something I predicted in the autumn 2020.

Based on what I wrote in methodological implications, if I were to start over, I would consider conducting a mixed method approach, consisting of an observational study, and questionnaires. I think this method would reduce the risk of the test samples being too small regardless of the global pandemic. As mentioned earlier, interviews was considered, in case there was a need for a more qualitative approach. If I were to plan this, I would have changed the approval contract to include the data collection method, and start with the testing process much earlier.

5.4.3 COVID-19

The research was conducted under the COVID-19 pandemic. I assumed the pandemic would make it much more difficult to conduct research than it have actually been. To start of, I was worried how the pandemic would influence the threshold for people to participate. The reason being, the VR headset was mounted on the face, and have been used by others. Although, disinfection procedures were conducted according to the Institute of Public Health (NIPH) guidelines before every use, it was natural to assume that these facts would make people sceptical.

In retrospect, people appeared less sceptical than anticipated throughout the recruitment process. It was positive to see that I was able to recruit 13 out of 157 students, which was more than I anticipated, considering the circumstances. More importantly, the pandemic was not the sole reason for the low participation, because there may exist other factors that influenced the recruitment process, for example, the data collection methods.

Luckily, we live in a society where most services were accessed digitally. This emphasises working from home, which often became a necessity due to the outbreak. I was writing my thesis in an online text editor, and used different digital communication channels to contact my advisers and Way. The pandemic was not a hindrance in terms of communication between the involved parties, or while writing the thesis. The transition from a physical to digital work space was manageable, because I had used previously used most online services before the pandemic occurred.

5.5 An interface inspection of Way's VR simulator

The simulator was analysed from an interaction design perspective, with the purpose to provide suggestions to support Way's future research. Disclaimer, this setup was a work in progress, and faults in the setup were expected. Therefore, the intention was to demonstrate some of my skills based on my field of study, and apply some of these practises when I address the simulator. The analysis consisted of two parts. The first part covers the VR simulator's physical, and hardware related interface. An overview of the suggestions are presented in Figure 5.2. The second part covers the software interface, including improvements to the course's interface. A couple of design examples are presented in Figure 5.4 and Figure 5.3

To start off, the button layout used in the experiment was not ideal compared to the standard layout in most cars, see Figure 5.2. An incorrect imitation of the car controls layout resulted in potential issues with the transfer process, which was important to address if Way were to conduct driving training with this setup. Firstly, the parking light was assigned on the same button as the short- and long beam. Instead, this button should only toggle between short or long beam, and parking lights should be assigned to a different button in proximity, to follow the Gestalt proximity principle. The setup's infrastructure did not allow the car engine to be started from the steering wheel, instead, it was started by the driving instructor. To give a better imitation of a real car, the student should be able to "start engine"-button themselves. The blinkers were assigned to the left and right button to enhance Don Normans Mapping principle. In addition, the warning triangle was assigned to the button with a triangle icon, to follow the Gestalt similarity principle. The button to toggle short and long beams was placed on the left side of the steering wheel, which was standard layout for most cars.

As previously mentioned, the VR headset included a hand tracking feature, which converted their real hands into virtual hands. This provided the driver with visual feedback of their hand movements when equipped with a VR HMD. On the other hand, there was no feet tracking, which made it difficult for some driver learners to place their feet correctly, especially, for the inexperienced. Although, feet tracking components can be tedious to implement, virtual feet can be visualised in other ways. For example, the simulation can be designed to visualise two feet in the preferred idle position. The virtual feet then moves according to the detected pedal input. The left foot toggles between the *rest* and *clutch* states, and the right foot toggles between *rest*, *gas*, and *brake* states.

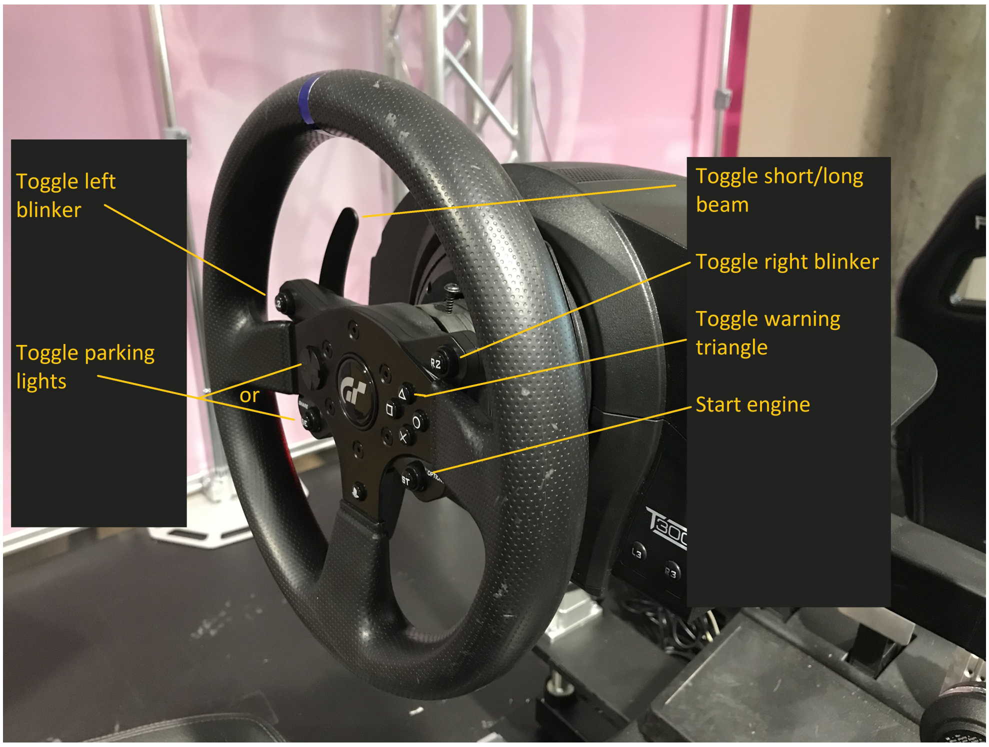

Figure 5.2: The Thrustmaster steering wheel with a suggested layout.

Interaction design helps a system to communicate its function to the user. In a way, this can be connected to the pedagogy. For example, a teacher had to manipulate information in such a way that the student understand a concept. In more technical terms, make their mental model equal to the conceptual model. Therefore, interaction design principles can be utilised to make the course more informative.

To rephrase, the virtual night driving course consisted of checkpoints, where the driver was presented with textual instructions or traffic theory on a billboard. The text was in Norwegian, and interpretation was needed to separate theory from instructions. This is only a speculation, but according to Gestalts similarity principle, the text of similar form or colour, may be perceived as the same type of information for the student. A solution to this, can be to assign a predefined colour to the instruction- and theory text, respectively. This will ensure that they are perceived differently, as shown in Figure 5.3. Which colour to choose, is a design challenge, but could be chosen based on an ISO standard or cultural background, which have the highest chance to apply for the majority. The colours chosen in the mockups are based on my personal cultural background and experience, and are only meant as examples. For example, I associate the colour *blue* with *learning*, such as the Way logo, which can be used to present theory. The colour *green* is used to represent *go* by traffic lights. The default colour may be used for instructions. However, maybe it would be more reasonable to associate the appropriate colour to match the term and symbol? The different approaches need to be user tested in design iterations, to verify their effects.

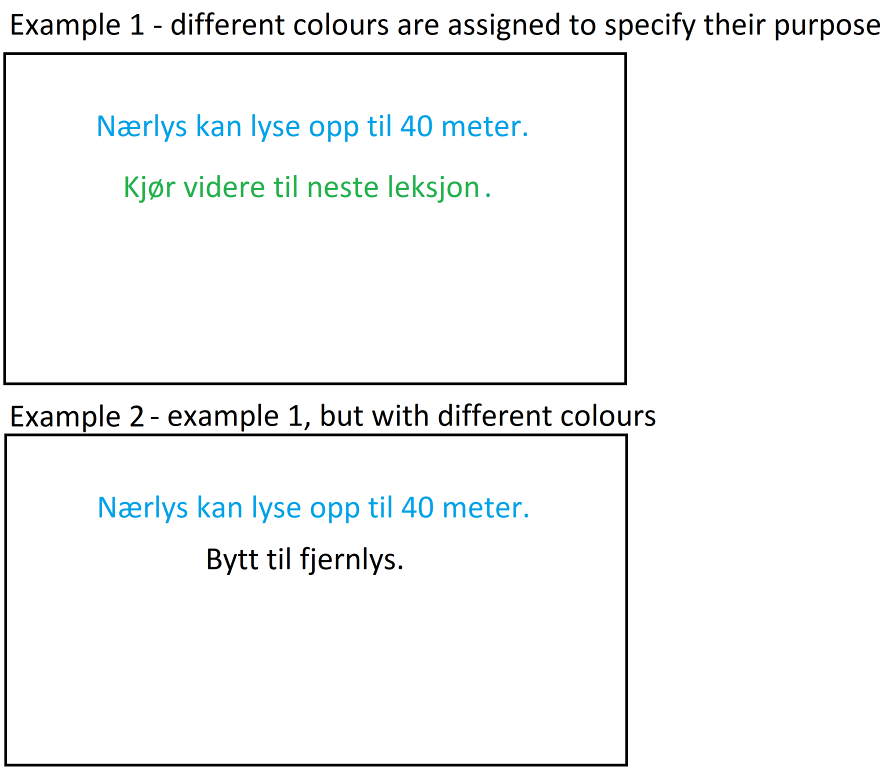

Figure 5.3: Two design examples for the billboard text, where instructions and theory were assigned their respective colours.

One universal design problem, is that a text-based course in Norwegian would make it difficult for illiterate or non-Norwegian students to complete the course without the help of a driving instructor. However, symbols make the lessons more informative in general through association. For example, by using symbols commonly found in cars, it can improve the transfer of knowledge in terms of car knowledge. Figure 5.4 shows three different design examples where a symbol was used to make the lesson more informative.

All in all, it is not certain that these suggestions would work as theorised, but these are meant to give an idea on possible changes, which I believe would improve the overall learning experience. The designs are only shown as simple examples, and need to be user tested in design cycles, until the budget runs out, or if the design provide the wanted outcome.

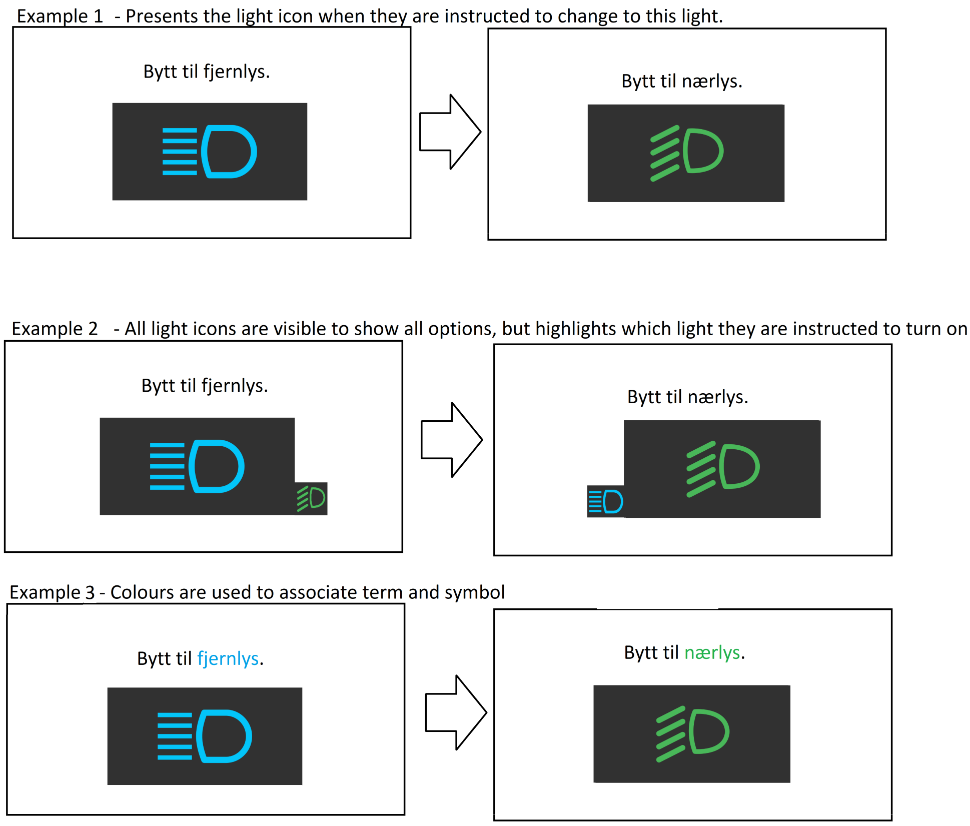

Figure 5.4: Three design examples for the billboard presentation, including icons to make the lesson more informative through association.

Chapter 6

Conclusion

To answer the main problem, three research questions were formed to assess three different aspects of this problem. These were presented in the introduction, and discussed in Chapter 5.

6.1 RQ1

Although, driving simulators were in the early phase of being implemented as a learning tool in the Norwegian driving training, recent research showed the motivation for a simulator-based learning approach due to its benefits. A simulated night driving course included beneficial aspects such as:

- a step towards standardised design on a national level
- a demonstration of manoeuvres
- being a more sustainable solution
- computerised, objectively assessment
- flexibility through stage-managing road conditions,traffic density, environment, weather, time etc.
- providing a safe work environment for driving instructors and driver learners
- targeted training
- the opportunity to conduct driving training independent of season or night hours.
- training in hazardous environments without putting others in danger
- unlimited repetition

However, there were legal concerns in Norway that had to be addressed before this learning tool can be utilised to pass mandatory activities, such as the night driving course. The VR solution must overcome a quality threshold in terms of hardware and software to be a good imitation, to ensure an optimal transfer of learning, and the retention of knowledge. It was decided to focus on the cost, an important technical limit, and the learning tool's effectiveness to evaluate whether this solution satisfies the legal concerns.

As for the simulator solution cost, it required adapted tutoring, including new learning patterns, methods. Moreover, staff must be trained to apply this as a part of their lessons. Although, a mid-level VR simulator's hardware was cheaper than a high fidelity simulator, expenses related to staff training, development, and maintenance still applied. On the other hand, the staff must be trained to use VR, and the simulation must be (re)designed to support VR as well. Thus, introduces additional costs in the long term.

The setup was a work in progress, and was missing elements that prevented it from being used to conduct part two of the simulated night driving course. However, results showed that the simulation covered the necessary learning goals, and the majority of students were overall satisfied with the setup as a learning tool. Meaning, the content of the simulation were perceived to have the desired quality, and the simulator setup gave a good driving experience. On the other hand, there was a noticeable limitation to the VR headset's resolution, which influenced the driving experience negatively. For example, signs were difficult to read from a distance. Because the ability to read road signs is a necessity when driving, it was concluded that the XTAL headset did not offer the necessary hardware quality, thus, the solution was not approved to be used to pass the night driving training.

6.2 RQ2

No SS symptoms were reported in the test case, and there was no significant difference between different gender or age, although, the majority of candidates were 15-16 years old and women. The sample size resulted in a risk uncertainty between 0-7,7% for a candidate to trigger SS. Therefore, there is a need to collect more test samples with testing tools, which are non-inferior to those used in this study. On the other hand, at most, a 7,7% chance to trigger SS was less than the reported amount in the study (Ihemedu-Steinke, Rangelova *et al.* 2017, p. 16), which also used full VA.

Furthermore, the simulation used full VA, which, according to the neural theory, helps reduce the risk of SS, as it improves the imitation of past experiences. Additionally, the sensory theory and the postural theory described in Section 2.4.2, suggest that a mismatch between perceived- and experienced motion increases the risk of triggering SS. A motion system reduced the sensory- and the postural instability mismatch by providing physical feedback, which reduced the mismatch between these, thus, reduced the risk of SS.

6.3 RQ3

The VR simulator's effectiveness was measured based on the change in traffic awareness, the difference between the expected and actual learning outcome, in terms of subjective and objective assessment, to answer whether it was able to provide a learning outcome non-inferior to the traditional course. Test results showed a positive change in the test subjects' traffic awareness after completing either course. However, there was a more positive change in their traffic awareness after completing the VR course, than the traditional course. Based on the majority of test subjects, the simulator was capable of providing the necessary learning aspects to cover all learning goals. Although, only part one of the night driving course was conducted in the simulator, more subjects thought the simulator managed to teach them more than the traditional approach. Based on the objective assessment, the test scores showed no significant difference between the VR- and the traditional course.

The solution was non-inferior in terms of influencing the traffic awareness, and the subjective- and objective assessment, thus, was non-inferior to the traditional approach, in terms of learning outcome.

6.4 Main problem

There are certain requirements that need to be fulfilled to conduct the practical, mandatory part of the night driving course, using a VR simulator solution, in the Norwegian driving education. The simulation has to be a good imitation, which requires a high quality course design, and graphical hardware to support this. The course design has to cover the necessary learning goals, and the design must address the possible challenges related to the retention of knowledge, and the transfer of learning to ensure optimal learning to be approved for driving training. Conclusively, the VR simulation-based learning approach was non-inferior to the traditional learning approach, in terms of influencing the test subjects' traffic awareness, as well as their subjective- and objective assessment, compared to their prerequisites.

In addition, to compensate for the risk of SS, a motion system was implemented. Based on existing SS theories, the motion system was able to reduce the mismatch between the perceived- and experienced motion. Therefore, the motion system can be used to reduce the risk of SS. Although, most of the simulator setup was viable to conduct night driving training, there was reported technological limitations due to the VR HMD's resolution. Visibility over long distances is a necessity when driving. Therefore, technological limits concludes that, unfortunately, the current VR simulator solution was not approved to conduct the mandatory night driving training.

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Appendix A

Additional Material

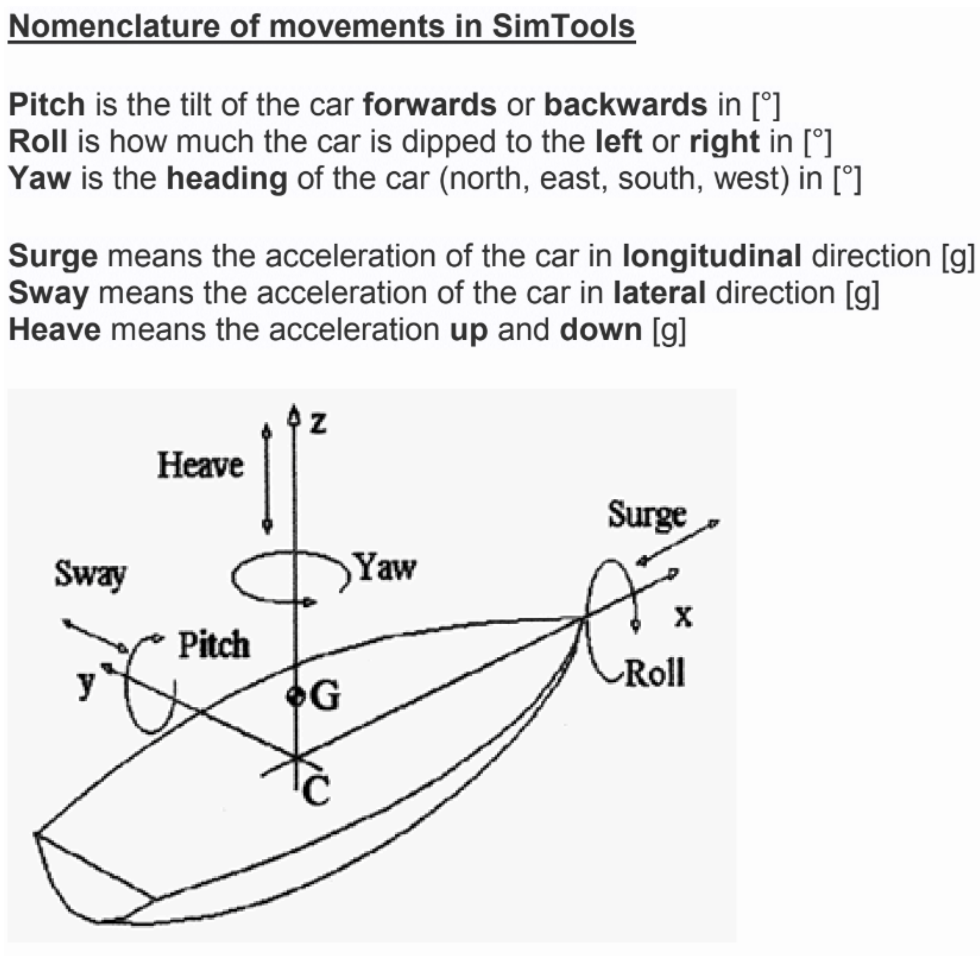

Figure A.1: Directional movements used by Simtools.

Appendix B

UDP packet content

```
{
    String.Format("{0},{1},{2},{3},{4},{5},{6},{7},{8}",
    simtools.Roll, simtools.Pitch, simtools.Yaw, simtools.Heave,
    simtools.Sway, simtools.Surge, simtools.Extra1, simtools.Extra2,
    simtools.Extra3);
}
```

Appendix C

Sintef's VR-lab activities

Aktivitetsområder

Oppdragsgiver	Tema	Prosjekt	VR Teknologi	Status
Singapore	FOU	Oppbygging av VR lab & Opplæring Metodikk	Gå plattform	Avsluttet
		3D modell av Science city		Avsluttet
		Støtte til student oppgave		Dialog pågår
	Nytt prosjekt	Evakuering eller automatiserte kjøretøy	Uavklart	Dialog pågår
Tryggt vegarbeid	Opplæring	Flaimtrainer	Simulering av brannslukking	Pågår
	Opplæring	Trafikkvakt	Gå uten plattform	Pågår
	Opplæring	Tungbil	Kjøresimulator	Pågår
Statens vegvesen	FOU Tunnel	Simulering av selvredning	Gå Simulator	Avsluttet
VD	FOU Tunnel	Effekt av ledelys i tunnel	Gå Simulator	Avsluttet
	FOU Tunnel	Simulering av opphold i redningsrom	Gå Simulator	Avsluttet
SVV-Norconsult	FOU Tunnel	E39 Rogfast Test av TS tiltak	Kjøresimulator	Avsluttet
SVV innovasjon Norge,Trafsys, SINTEF Digital	FOU Tunnel	0-visjon i tunnel, Evacsound	Gå simulator	Avsluttet
Universitetet i Stavanger (NFR)	FOU Tunnel	Effekt av info kampanje	Kjøresimulator	Avsluttet
Universitetet i Stavanger (NFR, Horizon 2020)	FOU Tunnel	3D modelering etc.		Dialog pågår
Trygg Trafikk	FOU	Barn og sykling	Sykkel simulator	Avsluttet
Nord Univ	Opplæring	Tungbil TS sjekk	Gå Simulator	Dialog pågår
Politiet	Opplæring	Utrykkning	Kjøresimulator	Dialog pågår
AVINOR	Opplæring	Flaimtrainer	Slukke simulator	Dialog pågår
SINTEF Ocean	Testmetodikk	Bruk av lab	Gå simulering u/plattform	Dialog pågår
Vegdir. FOU stab	FOU	Mulightsstudie	Kjøresimulator	Dialog pågår
SINTEF Digital	FOU	MC hjelm og TS	MC Simulator	Dialog pågår

Appendix D

An overview of possible simulator sickness symptoms

Simulator sickness

General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eye strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
"Fullness of the head"	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed)	None	Slight	Moderate	Severe
Vertigo (Giddiness)	None	Slight	Moderate	Severe
Stomach awareness	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

Appendix E

Questionnaire 1 (Pre-RL-Q)

Rapport fra «Evalueringsskjema før gjennomført mørkekurs»

Innhentede svar pr. 14. januar 2021 20:11

- Leverte svar: **1**
- Påbegynte svar: **0**
- Antall invitasjoner sendt: **1**

Med fritekstsvar

Praktisk info

Spørreundersøkelsen foregår under et master prosjekt på NTNU. Prosjektlederen heter [redacted] som studerer Master of Computer Science - Interaction Design, Game- and Learning Technology. Spørreundersøkelsen er sammensatt av flere spørreskjemaer.

Dette spørreskjemaet er ment for å kartlegge forkunnskaper, forventninger og holdninger til det obligatoriske mørkekjøringskurset organisert av Way trafikkskole. Alle spørsmål er obligatoriske. Har du spørsmål, kan du kontakte prosjektansvarlig før-, under- eller etter gjennomføring.

Dersom du ikke ønsker å delta, kan du lukke skjemaet uten å oppgi grunn. Hvis du har svart på skjemaet og angrer i etterkant, kontakt prosjektansvarlig for å slette besvarelsen din.

Minner om at dine svar ikke vil påvirke ditt forhold med trafikkskolen eller din kjøreopplæring.

OBS! Juks er **ødeleggende** for forskningen. Hensikten er ikke å evaluere deg som person, men å evaluere kvaliteten til kurset. Svarene dine har størst verdi, dersom du gjennomfører spørreskjemaet individuelt og ikke i samarbeid med internett eller andre deltakere.

Kontakt informasjon

Prosjektansvarlig, Master Student

[redacted]

E-post: [redacted]

Mob: [redacted]

Førsteamanuensis, Veiledende Professor

[redacted]

E-post: [redacted]

Mob: [redacted]

NTNUs Personvernombud

[redacted]

E-post: [redacted]

Mob: [redacted]

Hva er din e-postadresse? *

- [redacted]

Jeg samtykker til at jeg har lest informasjonen og samtykker til deltakelse *

Dette inkluderer også at foresatt har signert kontrakt for samtykke.

Svar	Antall	Prosent	
Ja	1	**100 %**	
Nei	0	**0 %**	

Har du gjennomført en mørkedemonstrasjon i VR simulator før du fikk dette skjemaet? *

Hvis du ikke har sittet i en simulator med VR briller på før du besvarer dette skjemaet, trykker du "Nei".

Svar	Antall	Prosent	
Ja	0	**0 %**	
Nei	1	**100 %**	

Holdningene når en ferdes i trafikken

Følgende påstander omhandler holdninger du har når du ferder i mørket og/eller i trafikken. Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Jeg bruker refleks i opplyst område *	0	1	0
Jeg ser meg for før jeg krysser veien i mørket *	0	1	0
Refleks kan gå ut på dato *	0	1	0
Jeg ser meg for, før jeg krysser veien i opplyst område *	0	1	0
Biler kan se meg, dersom frontlysene treffer meg *	0	1	0
Biler kan se meg i opplyste områder *	0	1	0
Flest fotgjengerulykker skjer i mørket *	0	1	0
Jeg bruker refleks når det er mørkt *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Jeg bruker refleks i opplyst område *	0 %	100 %	0 %
Jeg ser meg for før jeg krysser veien i mørket *	0 %	100 %	0 %
Refleks kan gå ut på dato *	0 %	100 %	0 %
Jeg ser meg for, før jeg krysser veien i opplyst område *	0 %	100 %	0 %
Biler kan se meg, dersom frontlysene treffer meg *	0 %	100 %	0 %
Biler kan se meg i opplyste områder *	0 %	100 %	0 %
Flest fotgjengerulykker skjer i mørket *	0 %	100 %	0 %
Jeg bruker refleks når det er mørkt *	0 %	100 %	0 %

Forventninger til mørkekjøringskurset

Hva tror du at du vil lære av kurset? Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Få innsikt i realistiske situasjoner *	0	1	0
Risikoforståelse i mørket, kontra dagslys *	0	1	0
Bruk av refleks *	0	1	0
Bruk av lys i mørket *	0	1	0
Bruk av lys i dagslys *	0	1	0
Lære om ulike lys på bilen *	0	1	0
Bruk av varseltrekanten *	0	1	0
Hvordan man kan se en fotgjenger i mørket *	0	1	0
Hvordan man kan kjøre fort i mørket *	0	1	0
Forskjellen på bruk/ikke bruk av refleks *	0	1	0
Hvordan siktstrekningen er i mørket *	0	1	0
Hvordan en ferdes på veien i mørket *	0	1	0
Hvordan bilen skal plasseres *	0	1	0
Hvilken faktor farten har i mørket *	0	1	0
Hvordan ulykker oppstår i mørket *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Få innsikt i realistiske situasjoner *	0 %	100 %	0 %
Risikoforståelse i mørket, kontra dagslys *	0 %	100 %	0 %
Bruk av refleks *	0 %	100 %	0 %
Bruk av lys i mørket *	0 %	100 %	0 %
Bruk av lys i dagslys *	0 %	100 %	0 %

Lære om ulike lys på bilen *	0 %	100 %	0 %
Bruk av varseltrekanten *	0 %	100 %	0 %
Hvordan man kan se en fotgjenger i mørket *	0 %	100 %	0 %
Hvordan man kan kjøre fort i mørket *	0 %	100 %	0 %
Forskjellen på bruk/ikke bruk av refleks *	0 %	100 %	0 %
Hvordan siktstrekningen er i mørket *	0 %	100 %	0 %
Hvordan en ferdes på veien i mørket *	0 %	100 %	0 %
Hvordan bilen skal plasseres *	0 %	100 %	0 %
Hvilken faktor farten har i mørket *	0 %	100 %	0 %
Hvordan ulykker oppstår i mørket *	0 %	100 %	0 %

Se nylige endringer i Nettskjema (v1039_0rc387)

Appendix F

Questionnaire 2 (Post-RL-Q)

Rapport fra «Evalueringsskjema etter gjennomført mørkekurs»

Innhentede svar pr. 14. januar 2021 20:08

- Leverte svar: **1**
- Påbegynte svar: **0**
- Antall invitasjoner sendt: **2**

Med fritekstsvar

Praktisk info

Spørreundersøkelsen foregår under et master prosjekt på NTNU. Prosjektlederen heter [redacted] som studerer Master of Computer Science - Interaction Design, Game- and Learning Technology. Spørreundersøkelsen er sammensatt av flere spørreskjemaer.

Dette spørreskjemaet er ment for å kartlegge holdninger og utbytte knyttet til det obligatoriske mørkekjøringskurset organisert av Way trafikkskole. Alle spørsmål er obligatoriske. Har du spørsmål, kan du kontakte prosjektansvarlig før-, under- eller etter gjennomføring.

Dersom du ikke ønsker å delta, kan du lukke skjemaet uten å oppgi grunn. Hvis du har svart på skjemaet og angrer i etterkant, kontakt prosjektansvarlig for å slette besvarelsen din.

Minner om at dine svar ikke vil påvirke ditt forhold med trafikkskolen eller din kjøreopplæring.

OBS! Juks er **ødeleggende** for forskningen. Hensikten er ikke å evaluere deg som person, men å evaluere kvaliteten til kurset. Svarene dine har størst verdi, dersom du gjennomfører spørreskjemaet individuelt og ikke i samarbeid med internett eller andre deltakere.

Kontakt informasjon

Prosjektansvarlig, Master Student

[redacted]

E-post: [redacted]

Mob: [redacted]

Førsteamanuensis, Veiledende Professor

[redacted]

E-post: [redacted]

Mob: [redacted]

NTNUs Personvernombud

[redacted]

E-post: [redacted]

Mob: [redacted]

Hva er din e-postadresse? *

Jeg samtykker til at jeg har lest informasjonen og samtykker til deltakelse *

Dette inkluderer også at foresatt har signert kontrakt for samtykke.

Svar	Antall	Prosent	
Ja	0	**0 %**	
Nei	0	**0 %**	

Har du gjennomført en mørkedemonstrasjon i VR simulator før du fikk dette skjemaet? *

Hvis du ikke har sittet i en simulator med VR briller på før du besvarer dette skjemaet, trykker du "Nei".

Svar	Antall	Prosent	
Ja	0	**0 %**	
Nei	1	**100 %**	

Holdningene når en ferdes i trafikken

Følgende påstander omhandler hvilke holdninger du sitter igjen med etter kurset. Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Jeg vil bruke refleks i opplyst område *	1	0	0
Jeg vil se meg for, før jeg krysser veien når det er mørkt *	0	1	0
Refleks kan gå ut på dato *	0	1	0
Jeg vil se meg for, før jeg krysser veien i opplyst område *	0	1	0
Biler kan se meg, dersom frontlysene treffer meg *	0	1	0
Biler kan se meg i opplyste områder *	0	0	1
Flest fotgjengerulykker skjer i mørket *	0	0	1
Jeg vil bruke refleks når det er mørkt *	0	0	1

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Jeg vil bruke refleks i opplyst område *	100 %	0 %	0 %
Jeg vil se meg for, før jeg krysser veien når det er mørkt *	0 %	100 %	0 %
Refleks kan gå ut på dato *	0 %	100 %	0 %
Jeg vil se meg for, før jeg krysser veien i opplyst område *	0 %	100 %	0 %
Biler kan se meg, dersom frontlysene treffer meg *	0 %	100 %	0 %
Biler kan se meg i opplyste områder *	0 %	0 %	100 %
Flest fotgjengerulykker skjer i mørket *	0 %	0 %	100 %
Jeg vil bruke refleks når det er mørkt *	0 %	0 %	100 %

Hva lærte du av mørkekjøringskurset?

Velg det som passer best for deg.

Jeg følte at jeg fikk innsikt i..

Svar fordelt på antall

	Uenig	Litt enig	Enig
..realistiske situasjoner *	1	0	0
..risikoforståelse i mørket, kontra dagslys *	1	0	0
..bruken av refleks *	0	1	0
..lysbruken i mørket *	0	1	0
..lysbruken i dagslys *	0	1	0
..de ulike lysene på bilen *	0	1	0
..bruk av varseltrekant *	0	1	0
..hvordan man kan kjøre fort i mørket *	0	1	0
..forskjellen på bruk/ikke bruk av refleks *	0	1	0
..hvordan siktstrekningen er i mørket *	0	1	0
..hvordan en ferdes på veien i mørket *	0	1	0
..hvordan bilen skal plasseres *	0	1	0
..hvilken faktor farten har i mørket *	0	1	0
..hvordan ulykker oppstår i mørket *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
..realistiske situasjoner *	100 %	0 %	0 %
..risikoforståelse i mørket, kontra dagslys *	100 %	0 %	0 %
..bruken av refleks *	0 %	100 %	0 %
..lysbruken i mørket *	0 %	100 %	0 %

..lysbruken i dagslys *	0 %	100 %	0 %
..de ulike lysene på bilen *	0 %	100 %	0 %
..bruk av varseltrekant *	0 %	100 %	0 %
..hvordan man kan kjøre fort i mørket *	0 %	100 %	0 %
..forskjellen på bruk/ikke bruk av refleks *	0 %	100 %	0 %
..hvordan siktstrekningen er i mørket *	0 %	100 %	0 %
..hvordan en ferdes på veien i mørket *	0 %	100 %	0 %
..hvordan bilen skal plasseres *	0 %	100 %	0 %
..hvilken faktor farten har i mørket *	0 %	100 %	0 %
..hvordan ulykker oppstår i mørket *	0 %	100 %	0 %

Opplevelsen av mørkekjøringsdemo

Følgende spørsmål omhandler opplevelsen av mørkekjøringsdemo.

Synes du at gjennomgangen klarte å vise deg..

Svar fordelt på antall

	Nei	Ja
..hva som er god og dårlig siktstrekning? *	0	1
..siktstrekningen som vist med antall meter sikt langs veien? *	0	1
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte? *	0	1
..et godt bilde på hvordan lysene på en bil skal virke? *	0	1
..når møtende bil har feil bruk av lys? *	0	1
..hvordan lysene skal brukes ved kjøring? *	0	1
..et godt inntrykk av hvordan farten skal tilpasses mørket? *	0	1
..et godt inntrykk av bilens plassering i mørket? *	0	1
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket? *	0	1
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør? *	0	1
..risikoforskjellen på når en ferdes i mørke, kontra dagslys? *	0	1

Svar fordelt på prosent

	Nei	Ja
..hva som er god og dårlig siktstrekning? *	0 %	100 %
..siktstrekningen som vist med antall meter sikt langs veien? *	0 %	100 %
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte? *	0 %	100 %
..et godt bilde på hvordan lysene på en bil skal virke? *	0 %	100 %
..når møtende bil har feil bruk av lys? *	0 %	100 %
..hvordan lysene skal brukes ved kjøring? *	0 %	100 %
..et godt inntrykk av hvordan farten skal tilpasses mørket? *	0 %	100 %
..et godt inntrykk av bilens plassering i mørket? *	0 %	100 %
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket? *	0 %	100 %
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør? *	0 %	100 %
..risikoforskjellen på når en ferdes i mørke, kontra dagslys? *	0 %	100 %

Besvar følgende spørsmål ut ifra hva du lærte fra kurset

Spørsmål 1 *

Hvor langt lyser nærlys?

Svar	Antall	Prosent	

Svar	Antall	Prosent	
Ca. 40 meter	1	**100 %**	
Ca. 100 meter	0	**0 %**	
Ca. 400 meter	0	**0 %**	

Spørsmål 2 *

Hvor langt lyser fjernlys?

Svar	Antall	Prosent	
Ca. 40 meter	0	**0 %**	
Ca. 100 meter	1	**100 %**	
Ca. 400 meter	0	**0 %**	

Spørsmål 3 *

Når er du først synlig for en bil som bruker nærlys, dersom du ikke bruker refleks?

Svar	Antall	Prosent	
10-15 meter	0	**0 %**	
25-30 meter	1	**100 %**	
40-50 meter	0	**0 %**	

Spørsmål 4 *

Hvilke lys er tillatt å bruke, dersom du stanser i høyre veikant?

Svar	Antall	Prosent	
Nærlys og nødsignallys	0	**0 %**	
Parklys eller ingen lys	1	**100 %**	
Alle lys er lov å bruke under stans	0	**0 %**	

Spørsmål 5 *

Hvilken påstand er sann?

Svar	Antall	Prosent	
Det er alltid lett å se at biler er i bevegelse når de bruker fjernlys eller nærlys i mørket	0	**0 %**	
Det er vanskelig å se at biler er i bevegelse når de bruker fjernlys eller nærlys i mørket	1	**100 %**	
Det har ingen betydning hvilke lys som brukes av biler i mørket for å vurdere avstand og fart	0	**0 %**	

Spørsmål 6 *

Hvor lang tid trenger øynene å tilpasse seg lyset, etter å ha vært lenge i mørket?

Svar	Antall	Prosent	
ca. 30 sekunder	0	**0 %**	
ca. 3 minutter	1	**100 %**	
ca. 30 minutter	0	**0 %**	

Spørsmål 7 *

Dersom du bruker refleks, på hvilken avstand er du synlig for en bil som bruker fjernlys?

Svar	Antall	Prosent	
ca. 40 meter	0	**0 %**	
ca. 100 meter	1	**100 %**	
ca. 400 meter	0	**0 %**	

Spørsmål 8 *

To biler møtes i mørket og skifter til nærlys. Hvilken påstand er sann?

Svar	Antall	Prosent	
Det danner seg et mørkt område mellom bilene, men det krever ikke ekstra oppmerksomhet	1	**100 %**	
Det danner seg et mørkt område mellom bilene som krever ekstra oppmerksomhet	0	**0 %**	
Det danner seg ikke et mørkt område fordi bilene bruker nærlys	0	**0 %**	

Spørsmål 9 *

To biler møtes i mørket og skifter til nærlys. Det danner seg et mørkt område mellom bilene. Hvilken påstand er sann?

Svar	Antall	Prosent	
Bilistene kan se fotgjengere uten refleks som ferdes i det mørke området	0	**0 %**	
Bilistene kan se fotgjengere med refleks som ferdes i det mørke området	1	**100 %**	
Lurespørsmål, det danner seg aldri et mørkt område mellom bilene når de bruker nærlys	0	**0 %**	

Spørsmål 10 *

Med hvor mange prosent reduseres risikoen for ulykke, dersom du går med synlig refleks?

Svar	Antall	Prosent	
ca. 85%	0	**0 %**	
ca. 55%	1	**100 %**	
ca. 35%	0	**0 %**	

Spørsmål 11 *

Hvordan påvirker fart risikoen for ulykke i mørket?

Svar	Antall	Prosent	
Farten må tilpasses sikt	0	**0 %**	
Farten har ingenting å si så lenge jeg bruker riktig lys	1	**100 %**	
Farten har liten betydningen i opplyste områder	0	**0 %**	

Spørsmål 12 *

Du ser en varseltrekant langs veikanten. Hvilken betydning har dette for din videre kjøring?

Svar	Antall	Prosent	
Det er viktig å opprettholde fart, men bruke riktig lys	1	**100 %**	
Senke farten og være ekstra oppmerksom	0	**0 %**	
Varseltrekanten indikerer at du skal sette på nødsignallys og stanse	0	**0 %**	

Spørsmål 13 *

Hvor skal refleksen henge?

Svar	Antall	Prosent	
Skulderhøyde	0	**0 %**	
Armhøyde	1	**100 %**	
Knehøyde	0	**0 %**	

Spørsmål 14 *

Hvilket lys benyttes for å se lengst mulig i mørket?

Svar	Antall	Prosent	
Fjernlys	0	**0 %**	
Nærlys	1	**100 %**	
Har ingen betydning	0	**0 %**	

Spørsmål 15 *

Hvilken kombinasjon av lys skal benyttes ved nødstopp i mørket?

Svar	Antall	Prosent	
Parklys og nødsignallys	0	**0 %**	
Nærlys og nødsignallys	0	**0 %**	
Fjernlys og nødsignallys	1	**100 %**	

Spørsmål 16 *

Hvor foregår flest fotgjengerulykker?

Svar	Antall	Prosent	
I tettbebygd område uten gatebelysning	0	**0 %**	
I tettbebygd område med gatebelysning	1	**100 %**	
På landevei uten gatebelysning	0	**0 %**	

Spørsmål 17 *

Er det påbudt med refleksvest i bilen?

Svar	Antall	Prosent	
Ja, den må ligge på en armelenges avstand fra føreren	1	**100 %**	
Ja, men det spiller ingen rolle hvor den ligger i bilen	0	**0 %**	
Nei, det er ikke påbudt, men sterkt anbefalt	0	**0 %**	

Spørsmål 18 *

To biler møtes og begge har slått av fjernlys. På hvilket tidspunkt skal bilene slå på fjernlys igjen?

Svar	Antall	Prosent	
2 billengder før de møtes	0	**0 %**	
Når bilene er ved siden av hverandre	1	**100 %**	
2 billengder etter at de har passert hverandre	0	**0 %**	

Spørsmål 19 *

Når skal du skru på fjernlysene under en forbikjøring?

Svar	Antall	Prosent	
Når du ligger 2 billenger bak bilen du kjører forbi	0	**0 %**	
Når du ligger ved siden av bilen du kjører forbi	1	**100 %**	
Når du har passert bilen du kjører forbi	0	**0 %**	

Spørsmål 20 *

Hva kan du gjøre for å unngå blending fra motgående trafikk når du kjører i mørket?

Svar	Antall	Prosent	
Rett blikket mot lysene til møtende bil	1	**100 %**	
Rett blikket fram og mot høyre veikant	0	**0 %**	
Rett blikket like framfor egen bil	0	**0 %**	

Se nylige endringer i Nettskjema (v1039_0rc387)

Appendix G

Questionnaire 3 (Pre-VR-Q)

Rapport fra «Evalueringsskjema før gjennomført mørkekurs i VR»

Innhentede svar pr. 14. januar 2021 20:17

- Leverte svar: **1**
- Påbegynte svar: **0**
- Antall invitasjoner sendt: **1**

Med fritekstsvar

Praktisk info

Spørreundersøkelsen foregår under et master prosjekt på NTNU. Prosjektlederen heter [redacted] som studerer Master of Computer Science - Interaction Design, Game- and Learning Technology. Spørreundersøkelsen er sammensatt av flere spørreskjemaer.

Dette spørreskjemaet er ment for å kartlegge forkunnskaper, forventninger og holdninger til det obligatoriske mørkekjøringskurset organisert av Way trafikkskole. I tillegg, erfaring og holdninger til VR teknologi. Alle spørsmål er obligatoriske. Har du spørsmål, kan du kontakte prosjektansvarlig før-, under- eller etter gjennomføring.

Dersom du ikke ønsker å delta, kan du lukke skjemaet uten å oppgi grunn. Hvis du har svart på skjemaet og angrer i etterkant, kontakt prosjektansvarlig for å slette besvarelsen din.

Minner om at dine svar ikke vil påvirke ditt forhold med trafikkskolen eller din kjøreopplæring.

OBS! Juks er **ødeleggende** for forskningen. Hensikten er ikke å evaluere deg som person, men å evaluere kvaliteten til kurset. Svarene dine har størst verdi, dersom du gjennomfører spørreskjemaet individuelt og ikke i samarbeid med internett eller andre deltakere.

Kontakt informasjon

Prosjektansvarlig, Master Student

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Førsteamanuensis, Veiledende Professor

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Mob: [redacted]

NTNUs Personvernombud

[redacted]

E-post: [redacted]

Mob: [redacted]

Hva er din e-postadresse? *

- [redacted]

Jeg samtykker til at jeg har lest informasjonen og samtykker til deltakelse *

Dette inkluderer også at foresatt har signert kontrakt for samtykke.

Svar	Antall	Prosent	
Ja	0	**0 %**	
Nei	1	**100 %**	

Har du gjennomført det obligatoriske mørkekjøringskurs ute før du besvarer dette skjemaet? *

Svar	Antall	Prosent	
Ja	1	**100 %**	
Nei	0	**0 %**	

Holdningene når en ferdes i trafikken

Følgende påstander omhandler holdninger du har når du ferder i mørket og/eller i trafikken. Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Jeg bruker refleks i opplyst område *	0	1	0
Jeg ser meg for før jeg krysser veien i mørket *	0	1	0
Refleks kan gå ut på dato *	0	1	0
Jeg ser meg for, før jeg krysser veien i opplyst område *	0	1	0
Biler kan se meg, dersom frontlysene treffer meg *	0	1	0
Biler kan se meg i opplyste områder *	0	1	0
Flest fotgjengerulykker skjer i mørket *	0	1	0
Jeg bruker refleks når det er mørkt *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Jeg bruker refleks i opplyst område *	0 %	100 %	0 %
Jeg ser meg for før jeg krysser veien i mørket *	0 %	100 %	0 %
Refleks kan gå ut på dato *	0 %	100 %	0 %
Jeg ser meg for, før jeg krysser veien i opplyst område *	0 %	100 %	0 %
Biler kan se meg, dersom frontlysene treffer meg *	0 %	100 %	0 %
Biler kan se meg i opplyste områder *	0 %	100 %	0 %
Flest fotgjengerulykker skjer i mørket *	0 %	100 %	0 %
Jeg bruker refleks når det er mørkt *	0 %	100 %	0 %

Forventninger til mørkekjøringskurset

Hva tror du at du vil lære av kurset? Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Få innsikt i realistiske situasjoner *	0	1	0
Risikoforståelse i mørket, kontra dagslys *	0	1	0
Bruk av refleks *	0	1	0
Bruk av lys i mørket *	0	1	0
Bruk av lys i dagslys *	0	1	0
Lære om ulike lys på bilen *	0	1	0
Bruk av varseltrekanten *	0	1	0
Hvordan man kan se en fotgjenger i mørket *	0	1	0
Hvordan man kan kjøre fort i mørket *	0	1	0
Forskjellen på bruk/ikke bruk av refleks *	0	1	0
Hvordan siktstrekningen er i mørket *	0	1	0
Hvordan en ferdes på veien i mørket *	0	1	0
Hvordan bilen skal plasseres *	0	1	0
Hvilken faktor farten har i mørket *	0	1	0
Hvordan ulykker oppstår i mørket *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Få innsikt i realistiske situasjoner *	0 %	100 %	0 %
Risikoforståelse i mørket, kontra dagslys *	0 %	100 %	0 %
Bruk av refleks *	0 %	100 %	0 %
Bruk av lys i mørket *	0 %	100 %	0 %

Bruk av lys i dagslys *	0 %	100 %	0 %
Lære om ulike lys på bilen *	0 %	100 %	0 %
Bruk av varseltrekanten *	0 %	100 %	0 %
Hvordan man kan se en fotgjenger i mørket *	0 %	100 %	0 %
Hvordan man kan kjøre fort i mørket *	0 %	100 %	0 %
Forskjellen på bruk/ikke bruk av refleks *	0 %	100 %	0 %
Hvordan siktstrekningen er i mørket *	0 %	100 %	0 %
Hvordan en ferdes på veien i mørket *	0 %	100 %	0 %
Hvordan bilen skal plasseres *	0 %	100 %	0 %
Hvilken faktor farten har i mørket *	0 %	100 %	0 %
Hvordan ulykker oppstår i mørket *	0 %	100 %	0 %

De neste spørsmålene vil omhandle erfaring og holdninger til VR teknologi.
Hvor mange timer erfaring har du med VR teknologi? *

Erfaring innebærer bruk av alle typer VR briller for underholdning, opplæring, arbeid eller annet. Velg det som ligger nærmest.

Svar	Antall	Prosent	
Aldri prøvd	0	**0 %**	
Under 1 time	0	**0 %**	
Mellom 1-5 timer	1	**100 %**	
Mellom 5-10 timer	0	**0 %**	
Mer enn 10 timer	0	**0 %**	

I hvilken forbindelse prøvde du VR brillene? *

Velg alle alternative som gjelder. Dersom du ikke finner alternativet ditt i listen, velg "Annet".

Svar	Antall	Prosent	
Underholdning (spill..)	1	**100 %**	
Underholdning (film, serie..)	0	**0 %**	
Utdanning (kurs, opplæring..)	0	**0 %**	
Utdanning (skoleprosjekt, innleveringer..)	0	**0 %**	
Jobb	0	**0 %**	
Annet	0	**0 %**	

Forventninger til opplevelsen i VR simulatoren

Følgende spørsmål omhandler forventninger til simulator opplevelsen. Velg det som passer best.

Jeg tror at..

Svar fordelt på antall

	Uenig	Litt enig	Enig
..VR teknologi har ingen fremtid i kjøreopplæring *	0	1	0
..man kan lære mer fra mørkedemo i VR simulator enn det som gjøres ute *	0	1	0
..simulatoren vil være realistisk *	0	1	0
..VR simulatoren kan erstatte deler av den obligatoriske kjøreopplæringen *	0	1	0
..VR simulatoren vil gi mer utbytte enn andre bilsimulatorer *	0	1	0
..VR simulator burde erstatte all obligatorisk kjøreopplæring *	0	1	0
..jeg vil lære mer av VR simulator fordi jeg hadde mer oversikt over omgivelsene *	0	1	0
..det vil være ubehagelig å bruke simulatoren *	0	1	0

..jeg vil klare å leve meg inn i den virtuelle verdenen *	0	1	0
..det er mer interessant å kjøre i simulator enn tradisjonell undervisning *	0	1	0
..jeg vil oppleve at farten er den samme som fartsmåleren viser i simulatoren *	0	1	0
..jeg vil føle at jeg sitter i en ekte bil *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
..VR teknologi har ingen fremtid i kjøreopplæring *	0 %	100 %	0 %
..man kan lære mer fra mørkedemo i VR simulator enn det som gjøres ute *	0 %	100 %	0 %
..simulatoren vil være realistisk *	0 %	100 %	0 %
..VR simulatoren kan erstatte deler av den obligatoriske kjøreopplæringen *	0 %	100 %	0 %
..VR simulatoren vil gi mer utbytte enn andre bilsimulatorer *	0 %	100 %	0 %
..VR simulator burde erstatte all obligatorisk kjøreopplæring *	0 %	100 %	0 %
..jeg vil lære mer av VR simulator fordi jeg hadde mer oversikt over omgivelsene *	0 %	100 %	0 %
..det vil være ubehagelig å bruke simulatoren *	0 %	100 %	0 %
..jeg vil klare å leve meg inn i den virtuelle verdenen *	0 %	100 %	0 %
..det er mer interessant å kjøre i simulator enn tradisjonell undervisning *	0 %	100 %	0 %
..jeg vil oppleve at farten er den samme som fartsmåleren viser i simulatoren *	0 %	100 %	0 %
..jeg vil føle at jeg sitter i en ekte bil *	0 %	100 %	0 %

Se nylige endringer i Nettskjema (v1039_0rc387)

Appendix H

Questionnaire 4 (Post-VR-Q)

Rapport fra «Evalueringsskjema etter gjennomført mørkekurs i VR»

Innhentede svar pr. 14. januar 2021 20:17

- Leverte svar: **1**
- Påbegynte svar: **0**
- Antall invitasjoner sendt: **1**

Med fritekstsvar

Praktisk info

Spørreundersøkelsen foregår under et master prosjekt på NTNU. Prosjektlederen heter [redacted] som studerer Master of Computer Science - Interaction Design, Game- and Learning Technology. Spørreundersøkelsen er sammensatt av flere spørreskjemaer.

Dette spørreskjemaet er ment for å kartlegge holdninger og erfaringen fra virtuell virkelighet (VR) teknologi etter gjennomføring av mørkekjøringskurset i VR. På slutten vil det være en flervalgsoppgave hvor du svarer etter beste evne. Alle spørsmål er obligatoriske. Har du spørsmål, kan du kontakte prosjektansvarlig før-, under- eller etter gjennomføring.

Dersom du ikke ønsker å delta, kan du lukke skjemaet uten å oppgi grunn. Hvis du har svart på skjemaet og angrer i etterkant, kontakt prosjektansvarlig for å slette besvarelsen din.

Minner om at dine svar ikke vil påvirke ditt forhold med Way trafikkskole eller din kjøreopplæring.

OBS! Juks er **ødeleggende** for forskningen. Hensikten er ikke å evaluere deg som person, men å evaluere kvaliteten til kurset. Svarene dine har størst verdi, dersom du gjennomfører spørreskjemaet individuelt og ikke i samarbeid med internett eller andre deltakere.

Kontakt informasjon

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Førsteamanuensis, Veiledende Professor

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E-post: [redacted]

Mob: [redacted]

NTNUs Personvernombud

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E-post: [redacted]

Mob: [redacted]

Hva er din e-postadresse? *

- [redacted]

Jeg samtykker til at jeg har lest informasjonen og samtykker til deltakelse *

Dette inkluderer også at foresatt har signert kontrakt for samtykke.

Svar	Antall	Prosent	
Ja	0	**0 %**	
Nei	1	**100 %**	

Har du gjennomført det obligatoriske mørkekjøringskurs ute før du besvarer dette skjemaet? *

Svar	Antall	Prosent	
Ja	1	**100 %**	
Nei	0	**0 %**	

Hvilket kjønn er du? *

Svar	Antall	Prosent	
Mann	1	**100 %**	

Svar	Antall	Prosent	
Kvinne	0	**0 %**	

Hvor gammel er du? *

- 24

Holdningene når en ferdes i trafikken

Følgende påstander omhandler hvilke holdninger du sitter igjen med etter kurset. Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Jeg vil bruke refleks i opplyst område *	0	1	0
Jeg vil se meg for, før jeg krysser veien når det er mørkt *	0	1	0
Refleks kan gå ut på dato *	0	1	0
Jeg vil se meg for, før jeg krysser veien i opplyst område *	0	1	0
Biler kan se meg, dersom frontlysene treffer meg *	0	1	0
Biler kan se meg i opplyste områder *	0	1	0
Flest fotgjengerulykker skjer i mørket *	0	1	0
Jeg vil bruke refleks når det er mørkt *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Jeg vil bruke refleks i opplyst område *	0 %	100 %	0 %
Jeg vil se meg for, før jeg krysser veien når det er mørkt *	0 %	100 %	0 %
Refleks kan gå ut på dato *	0 %	100 %	0 %
Jeg vil se meg for, før jeg krysser veien i opplyst område *	0 %	100 %	0 %
Biler kan se meg, dersom frontlysene treffer meg *	0 %	100 %	0 %
Biler kan se meg i opplyste områder *	0 %	100 %	0 %
Flest fotgjengerulykker skjer i mørket *	0 %	100 %	0 %
Jeg vil bruke refleks når det er mørkt *	0 %	100 %	0 %

Hva lærte du av mørkekjøringskurset?

Velg det som passer best for deg.

Jeg følte at jeg fikk innsikt i..

Svar fordelt på antall

	Uenig	Litt enig	Enig
..realistiske situasjoner *	0	1	0
..risikoforståelse i mørket, kontra dagslys *	0	1	0
..bruken av refleks *	0	1	0
..lysbruken i mørket *	0	1	0
..lysbruken i dagslys *	0	1	0
..de ulike lysene på bilen *	0	1	0
..bruk av varseltrekant *	0	1	0
..hvordan man kan kjøre fort i mørket *	0	1	0
..forskjellen på bruk/ikke bruk av refleks *	0	1	0
..hvordan siktstrekningen er i mørket *	0	1	0
..hvordan en ferdes på veien i mørket *	0	1	0
..hvordan bilen skal plasseres *	0	1	0
..hvilken faktor farten har i mørket *	0	1	0

..hvordan ulykker oppstår i mørket *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
..realistiske situasjoner *	0 %	100 %	0 %
..risikoforståelse i mørket, kontra dagslys *	0 %	100 %	0 %
..bruken av refleks *	0 %	100 %	0 %
..lysbruken i mørket *	0 %	100 %	0 %
..lysbruken i dagslys *	0 %	100 %	0 %
..de ulike lysene på bilen *	0 %	100 %	0 %
..bruk av varseltrekant *	0 %	100 %	0 %
..hvordan man kan kjøre fort i mørket *	0 %	100 %	0 %
..forskjellen på bruk/ikke bruk av refleks *	0 %	100 %	0 %
..hvordan siktstrekningen er i mørket *	0 %	100 %	0 %
..hvordan en ferdes på veien i mørket *	0 %	100 %	0 %
..hvordan bilen skal plasseres *	0 %	100 %	0 %
..hvilken faktor farten har i mørket *	0 %	100 %	0 %
..hvordan ulykker oppstår i mørket *	0 %	100 %	0 %

Opplevelsen av mørkekjøringsdemo i simulator

Følgende spørsmål omhandler opplevelsen av mørkekjøringsdemo.

Synes du at gjennomgangen klarte å vise deg..

Svar fordelt på antall

	Nei	Ja
..hva som er god og dårlig siktstrekning? *	0	1
..siktstrekningen som vist med antall meter sikt langs veien? *	0	1
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte? *	0	1
..et godt bilde på hvordan lysene på en bil skal virke? *	0	1
..når møtende bil har feil bruk av lys? *	0	1
..hvordan lysene skal brukes ved kjøring? *	0	1
..et godt inntrykk av hvordan farten skal tilpasses mørket? *	0	1
..et godt inntrykk av bilens plassering i mørket? *	0	1
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket? *	0	1
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør? *	0	1
..risikoforskjellen på når en ferdes i mørke, kontra dagslys? *	0	1

Svar fordelt på prosent

	Nei	Ja
..hva som er god og dårlig siktstrekning? *	0 %	100 %
..siktstrekningen som vist med antall meter sikt langs veien? *	0 %	100 %
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte? *	0 %	100 %
..et godt bilde på hvordan lysene på en bil skal virke? *	0 %	100 %
..når møtende bil har feil bruk av lys? *	0 %	100 %
..hvordan lysene skal brukes ved kjøring? *	0 %	100 %
..et godt inntrykk av hvordan farten skal tilpasses mørket? *	0 %	100 %
..et godt inntrykk av bilens plassering i mørket? *	0 %	100 %
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket? *	0 %	100 %
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør? *	0 %	100 %

..risikoforskjellen på når en ferdes i mørke, kontra dagslys? *	0 %	100 %

Holdninger og meninger om mørkekjøringsdemo i simulator

Følgende spørsmål omhandler holdninger og meninger av mørkekjøringsdemo. Velg det som passer best for deg.

Svar fordelt på antall

	Uenig	Litt enig	Enig
Jeg føler at det er bedre å gjennomføre kurset inne *	0	1	0
Jeg ville heller gjort dette inne hvis jeg kunne *	0	1	0
Jeg synes at kurset var spennende *	0	1	0
Jeg følte at det alltid var lett å få med seg hva som skjedde *	0	1	0
Jeg har troen på at dette kan brukes til å gjennomføre kurset hele året *	0	1	0
Hvis mulig, hadde jeg heller gjennomført kurset tettere opp mot førerprøven hvor jeg kunne få kjøre selv *	0	1	0
Jeg synes at det å kjøre med to elever sammen er en god løsning *	0	1	0
Jeg følte at simulatoren gikk igjennom læringsmålene for fort *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig
Jeg føler at det er bedre å gjennomføre kurset inne *	0 %	100 %	0 %
Jeg ville heller gjort dette inne hvis jeg kunne *	0 %	100 %	0 %
Jeg synes at kurset var spennende *	0 %	100 %	0 %
Jeg følte at det alltid var lett å få med seg hva som skjedde *	0 %	100 %	0 %
Jeg har troen på at dette kan brukes til å gjennomføre kurset hele året *	0 %	100 %	0 %
Hvis mulig, hadde jeg heller gjennomført kurset tettere opp mot førerprøven hvor jeg kunne få kjøre selv *	0 %	100 %	0 %
Jeg synes at det å kjøre med to elever sammen er en god løsning *	0 %	100 %	0 %
Jeg følte at simulatoren gikk igjennom læringsmålene for fort *	0 %	100 %	0 %

Holdninger til VR simulator som et læringsverktøy i kjøreopplæringen

Følgende spørsmål dekker omfang av din mening om bruk av VR teknologi i kjøreopplæring. Velg det som passer best.

Svar fordelt på antall

	Uenig	Litt enig	Enig
VR teknologi har ingen fremtid i kjøreopplæring *	0	1	0
Man kan lære mer fra mørkedemo i VR simulator enn det som gjøres ute *	0	1	0
Jeg opplevde at simulatoren var realistisk *	0	1	0
VR simulatoren kan erstatte deler av den obligatoriske kjøreopplæringen *	0	1	0
VR simulatoren gir ikke mer utbytte enn andre bilsimulatorer *	0	1	0
VR burde erstatte all obligatorisk kjøreopplæring *	0	1	0
Jeg lærer mer av VR simulator fordi jeg hadde mer oversikt over omgivelsene *	0	1	0
VR kan erstatte deler eller all obligatorisk kjøreopplæring *	0	1	0
Det var ubehagelig å bruke simulatoren *	0	1	0
Jeg klarte å leve meg inn i verdenen når jeg var i simulator *	0	1	0
Det var gøyere å kjøre i simulator enn å være med på tradisjonell (ute) mørkedemo *	0	1	0
Jeg opplevde at farten var den samme som fartsmåleren viste *	0	1	0
I simulatoren følte jeg at jeg satt i en ekte bil *	0	1	0

Svar fordelt på prosent

	Uenig	Litt enig	Enig

VR teknologi har ingen fremtid i kjøreopplæring *	0 %	100 %	0 %
Man kan lære mer fra mørkedemo i VR simulator enn det som gjøres ute *	0 %	100 %	0 %
Jeg opplevde at simulatoren var realistisk *	0 %	100 %	0 %
VR simulatoren kan erstatte deler av den obligatoriske kjøreopplæringen *	0 %	100 %	0 %
VR simulatoren gir ikke mer utbytte enn andre bilsimulatorer *	0 %	100 %	0 %
VR burde erstatte all obligatorisk kjøreopplæring *	0 %	100 %	0 %
Jeg lærer mer av VR simulator fordi jeg hadde mer oversikt over omgivelsene *	0 %	100 %	0 %
VR kan erstatte deler eller all obligatorisk kjøreopplæring *	0 %	100 %	0 %
Det var ubehagelig å bruke simulatoren *	0 %	100 %	0 %
Jeg klarte å leve meg inn i verdenen når jeg var i simulator *	0 %	100 %	0 %
Det var gøyere å kjøre i simulator enn å være med på tradisjonell (ute) mørkedemo *	0 %	100 %	0 %
Jeg opplevde at farten var den samme som fartsmåleren viste *	0 %	100 %	0 %
I simulatoren følte jeg at jeg satt i en ekte bil *	0 %	100 %	0 %

Ble du simulator syk eller dårlig under simuleringen? *

Simulator syke kan sammenliknes med "bilsyke", og inkluderer symptomer som hodepine, vondt i øynene, kaldsvette, uggenhet eller kvalme, svimmelhet e.l.

Svar	Antall	Prosent	
Ja	1	**100 %**	
Nei	0	**0 %**	

Hvilke symptomer hadde du under- eller etter simulator opplevelsen? *

Dersom du ikke finner alternativet ditt under, velg "Annet". Velg minst ett alternativ.

Svar	Antall	Prosent	
Svimmelhet	0	**0 %**	
Hodepine	0	**0 %**	
Kastet opp	0	**0 %**	
Kvalme eller uggenhet	0	**0 %**	
Kaldsvette	1	**100 %**	
Øyeverk, vondt i øyene eller sliten i øynene	1	**100 %**	
Ekstra trøtthet	0	**0 %**	
Annet	0	**0 %**	

Besvar følgende spørsmål ut ifra hva du lærte fra kurset
Spørsmål 1 *

Hvor langt lyser nærlys?

Svar	Antall	Prosent	
Ca. 40 meter	0	**0 %**	
Ca. 100 meter	1	**100 %**	
Ca. 400 meter	0	**0 %**	

Spørsmål 2 *

Hvor langt lyser fjernlys?

Svar	Antall	Prosent	
Ca. 40 meter	0	**0 %**	
Ca. 100 meter	1	**100 %**	
Ca. 400 meter	0	**0 %**	

Spørsmål 3 *

Når er du først synlig for en bil som bruker nærlys, dersom du ikke bruker refleks?

Svar	Antall	Prosent	
10-15 meter	0	**0 %**	
25-30 meter	1	**100 %**	
40-50 meter	0	**0 %**	

Spørsmål 4 *

Hvilke lys er tillatt å bruke, dersom du stanser i høyre veikant?

Svar	Antall	Prosent	
Nærlys og nødsignallys	0	**0 %**	
Parklys eller ingen lys	1	**100 %**	
Alle lys er lov å bruke under stans	0	**0 %**	

Spørsmål 5 *

Hvilken påstand er sann?

Svar	Antall	Prosent	
Det er alltid lett å se at biler er i bevegelse når de bruker fjernlys eller nærlys i mørket	0	**0 %**	
Det er vanskelig å se at biler er i bevegelse når de bruker fjernlys eller nærlys i mørket	1	**100 %**	
Det har ingen betydning hvilke lys som brukes av biler i mørket for å vurdere avstand og fart	0	**0 %**	

Spørsmål 6 *

Hvor lang tid trenger øynene å tilpasse seg lyset, etter å ha vært lenge i mørket?

Svar	Antall	Prosent	
ca. 30 sekunder	0	**0 %**	
ca. 3 minutter	1	**100 %**	
ca. 30 minutter	0	**0 %**	

Spørsmål 7 *

Dersom du bruker refleks, på hvilken avstand er du synlig for en bil som bruker fjernlys?

Svar	Antall	Prosent	
ca. 40 meter	0	**0 %**	
ca. 100 meter	1	**100 %**	
ca. 400 meter	0	**0 %**	

Spørsmål 8 *

To biler møtes i mørket og skifter til nærlys. Hvilken påstand er sann?

Svar	Antall	Prosent	
Det danner seg et mørkt område mellom bilene, men det krever ikke ekstra oppmerksomhet	0	**0 %**	
Det danner seg et mørkt område mellom bilene som krever ekstra oppmerksomhet	1	**100 %**	
Det danner seg ikke et mørkt område fordi bilene bruker nærlys	0	**0 %**	

Spørsmål 9 *

To biler møtes i mørket og skifter til nærlys. Det danner seg et mørkt område mellom bilene. Hvilken påstand er sann?

Svar	Antall	Prosent	
Bilistene kan se fotgjengere uten refleks som ferdes i det mørke området	0	**0 %**	
Bilistene kan se fotgjengere med refleks som ferdes i det mørke området	1	**100 %**	
Bilistene skal skru på fjernlys igjen for å se hva som er i det mørke området	0	**0 %**	

Spørsmål 10 *

Med hvor mange prosent reduseres risikoen for ulykke, dersom du går med synlig refleks?

Svar	Antall	Prosent	
ca. 85%	0	**0 %**	
ca. 55%	1	**100 %**	
ca. 35%	0	**0 %**	

Spørsmål 11 *

Hvordan påvirker fart risikoen for ulykke i mørket?

Svar	Antall	Prosent	
Farten må tilpasses sikt	0	**0 %**	
Farten har ingenting å si så lenge jeg bruker riktig lys	1	**100 %**	
Farten har liten betydningen i opplyste områder	0	**0 %**	

Spørsmål 12 *

Du ser en varseltrekant langs veikanten. Hvilken betydning har dette for din videre kjøring?

Svar	Antall	Prosent	
Det er viktig å opprettholde fart, men bruke riktig lys	0	**0 %**	
Senke farten og være ekstra oppmerksom	1	**100 %**	
Varseltrekanten indikerer at du skal sette på nødsignallys og stanse	0	**0 %**	

Spørsmål 13 *

Hvor skal refleksen henge?

Svar	Antall	Prosent	
Skulderhøyde	0	**0 %**	
Armhøyde	1	**100 %**	
Knehøyde	0	**0 %**	

Spørsmål 14 *

Hvilket lys benyttes for å se lengst mulig i mørket?

Svar	Antall	Prosent	
Fjernlys	0	**0 %**	
Nærlys	1	**100 %**	
Har ingen betydning	0	**0 %**	

Spørsmål 15 *

Hvilken kombinasjon av lys skal benyttes ved nødstopp i mørket?

Svar	Antall	Prosent	
Parklys og nødsignallys	0	0 %	
Nærlys og nødsignallys	1	100 %	
Fjernlys og nødsignallys	0	0 %	

Spørsmål 16 *

Hvor foregår flest fotgjengerulykker?

Svar	Antall	Prosent	
I tettbebygd område uten gatebelysning	0	0 %	
I tettbebygd område med gatebelysning	1	100 %	
På landevei uten gatebelysning	0	0 %	

Spørsmål 17 *

Er det påbudt med refleksvest i bilen?

Svar	Antall	Prosent	
Ja, den må ligge på en armelenges avstand fra føreren	0	0 %	
Ja, men det spiller ingen rolle hvor den ligger i bilen	1	100 %	
Nei, det er ikke påbudt, men sterkt anbefalt	0	0 %	

Spørsmål 18 *

To biler møtes og begge har slått av fjernlys. På hvilket tidspunkt skal bilene slå på fjernlys igjen?

Svar	Antall	Prosent	
2 billengder før de møtes	0	0 %	
Når bilene er ved siden av hverandre	1	100 %	
2 billengder etter at de har passert hverandre	0	0 %	

Spørsmål 19 *

Når skal du skru på fjernlysene under en forbikjøring?

Svar	Antall	Prosent	
Når du ligger 2 billenger bak bilen du kjører forbi	0	0 %	
Når du ligger ved siden av bilen du kjører forbi	1	100 %	
Når du har passert bilen du kjører forbi	0	0 %	

Spørsmål 20 *

Hva kan du gjøre for å unngå blending fra motgående trafikk når du kjører i mørket?

Svar	Antall	Prosent	
Rett blikket mot lysene til møtende bil	0	0 %	
Rett blikket fram og mot høyre veikant	1	100 %	
Rett blikket like framfor egen bil	0	0 %	

Se nylige endringer i Nettskjema (v1039_0rc387)

Appendix I

Contract of approval

Vil du delta i forskningsprosjektet

"I retning mot billappen i VR: assistere unge sjåfører å lære og kjøre trygt i Norge ved bruk av VR teknologi"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å *sammenligne læringsutbyttet etter å ha gjennomført kurset "mørkekjøring" i virtuell virkelighet (VR) simulator- og gjennom tradisjonell opplæring.* I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet er å utforske muligheter en VR simulator har som et læringsverktøy eller arbeidsmåte. Dette innebærer at deltakere vil gjennomføre mørkekjøringskurs hvor demonstrasjonen gjøres ute og i simulator. For å måle kvaliteten og utbytte fra hvert enkelt kurs vil læringsutbyttet bli målt og analysert etter hvert kurs gjennom spørreskjemaer. I forbindelse med simulator syke, også kalt "bilsyke", vil deltakerens alder, kjønn og helseforhold bli samlet inn for å bidra til forskningen på dette området. Omfanget av prosjektet er avgrenset til mørkekjøringskurset levert av trafikkskolen Way AS og prosjektets varighet er frem til 1. juni 2021. Forskningsprosjektet er en masteroppgave på Gløshaugen, NTNU, innenfor fagfeltet Master i Informatikk - Interaksjonsdesign, Spill- og Læringsteknologi.

Følgende problemstilling skal besvares:

> *Hvordan kan læringsutbyttet fra mørkekjøringskurset være minst like bra ved å bruke VR teknologi som en del av opplæringen sammenlignet med tradisjonell opplæring?*

Følgende informasjon skal samles inn:

- Personlig epost
- Alder
- Kjønn
- Helseforhold

Hvem er ansvarlig for forskningsprosjektet?

Norges teknisk-naturvitenskapelige universitet - NTNU er ansvarlig for prosjektet. Forskningsprosjektet gjøres i samarbeid med trafikkskolen Way AS.

Hvorfor får du spørsmål om å delta?

For å kunne sammenligne læringsutbyttet etter gjennomført mørkekjøringskurs vil det trekkes X vilkårlige kandidater fra trafikkskolens elever. Kriteriene for å bli valgt ut er at deltakeren må være en elev hos Way trafikkskole og har, eller skal, gjennomføre mørkekjøring i perioden høsten 2020 til våren 2021 hos Way trafikkskole.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet innebærer dette at du skal delta på to mørkekjøringskurs i tilfeldig rekkefølge. Den ene vil gjennomføres normalt ute i bil med instruktør, mens den andre vil være i en av simulatorene til trafikkskolen. Obligatorisk mørkekjøringskurs tar normal tid å gjennomføre og det tar deg ca. 1 time å gjennomføre mørkedemonstrasjonen i VR simulator. Det vil være totalt 4 skjemaer du vil bli bedt om å fylle ut som vil ta deg ca 5-10 min. Spørreskjemaene vil inneholde spørsmål og påstander om forventninger til kurset og forventet læringsutbytte. I tillegg inneholder de også spørsmål om holdninger og meninger om VR teknologi samt simulator syke. Spørsmålene besvares enten gjennom flervalgsspørsmål med tre alternativer eller med en skala på følgende format: "Enig - Litt enig - Uenig". Spørsmål i forbindelse med helseforhold etter utprøving av VR simulator vil være av typen "Opplevde du verk i øynene?". Spørreskjemaer vil bli sendt til deltakerens epost og vil bli brukt til å koble besvarelser på tvers av spørreskjemaer sammen. Dine svar fra spørreskjemaet blir registrert elektronisk.

Merk! For deltakere under 18 år har foreldre/foresatte rett til å få se spørreskjemaene på forhånd ved å ta kontakt med prosjektansvarlig.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi grunn. Alle dine opplysninger relatert til prosjektet vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Det vil ikke påvirke ditt forhold til trafikkskolen eller prosessen mot å ta lappen hos trafikkskolen. Mørkekjøringskurset levert av trafikkskolen er obligatorisk i kjøreopplæringen og må gjennomføres uavhengig av forskningsprosjektet for å kunne øvelseskjøre. Dersom du trekker samtykket tilbake behøver du ikke å gjennomføre mørkekjøringskurset i simulator eller besvare noen flere spørreskjemaer.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Resultatene fra spørreundersøkelsene vil bli lagret kryptert på NTNUs servere. Master student og veiledende professor ved behandlingsansvarlig institusjon har tilgang til resultatene fra spørreskjemaene som inkluderer kjønn, alder, epost, helseforhold og øvrige besvarelser.

Universitetet i Oslo - UiO er leverandør av nettskjema tjenesten og står for lagring av resultatene i spørreskjemaet. UiO har intern databehandlingsavtale med NTNU. Resultatene vil bli behandlet etter innsamling slik at deltakerne ikke vil kunne gjenkjennes i publikasjonen.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 1. juni 2021. Etter innsamling av data fra spørreskjemaene vil resultatene bli anonymisert gjennom grovkategorisering slik at ingen enkeltpersoner kan gjenkjennes i datamaterialet. For eksempel, innebærer dette å erstatte epost adressen med en vilkårlig kandidat id.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges teknisk-naturvitenskapelige universitet - NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Norges teknisk-naturvitenskapelige universitet - NTNU ved
  Master Student
  [redacted]
  E-post: [redacted]
  Mob: [redacted]

  Førsteamanuensis
  [redacted]
  E-post: [redacted]
  Mob: [redacted]

- Vårt personvernombud:
  NTNUs personvernombud
  [redacted]
  E-post: [redacted]
  Mob: [redacted]

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost ([redacted]) eller på telefon: [redacted].

Med vennlig hilsen

Master student ved NTNU og prosjektansvarlig,
[redacted]

(Forsker/Student)
[redacted]

Samtykkeerklæring

-

Jeg har mottatt og forstått informasjon om prosjektet "I retning mot billappen i VR: assistere unge sjåfører å lære og kjøre trygt i Norge ved bruk av VR teknologi", og har fått anledning til å stille spørsmål. Jeg samtykker til:

- □ å delta i spørreskjema

Jeg samtykker til at prosjektdeltakerens opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltakers verge/foreldre, dato)

Appendix J

Tables presenting the results in Norwegian

Table J.1: The table shows how the traffic awareness for the control group was affected by the VR course. The VR course did not negatively influence their awareness in any statement.

Control Group	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Jeg bruker refleks i opplyst område	50%	0%	50%	0%	0%	100%	**50%**
Jeg ser meg for før jeg krysser veien i mørket	0%	0%	100%	0%	0%	100%	**0%**
Refleks kan gå ut på dato	50%	0%	50%	0%	50%	50%	**50%**
Jeg ser meg for, før jeg krysser veien i opplyst område	0%	0%	100%	0%	0%	100%	**0%**
Jeg bruker refleks når det er mørkt	0%	0%	100%	0%	0%	100%	**0%**
These statements are positive if they disagree.							**Positive if <= 0%**
Biler kan se meg, dersom frontlysene treffer meg	0%	0%	100%	50%	50%	0%	**-100%**
Biler kan se meg i opplyste områder	0%	0%	100%	0%	100%	0%	**-100%**
Flest fotgjengerulykker skjer i mørket	0%	50%	50%	0%	50%	50%	**0%**

Table J.2: The table shows how the traffic awareness for subjects in group 2 was affected by the traditional course. In 6 of 8 statements, the RL course positively influenced their traffic awareness.

Group 2 (RL)	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Jeg bruker refleks i opplyst område	45,4%	27,3%	27,3%	9,1%	27,3%	63,6%	**36,3%**
Jeg ser meg for før jeg krysser veien i mørket	0%	0%	100%	0%	0%	100%	**0%**
Refleks kan gå ut på dato	18,2%	0%	81,8%	9,1%	0%	90,9%	**9,1%**
Jeg ser meg for, før jeg krysser veien i opplyst område	0%	0%	100%	0%	0%	100%	**0%**
Jeg bruker refleks når det er mørkt	27,3%	27,3%	45,4%	0%	9,1%	90,9%	**45,5%**
These statements are positive if they disagree.							**Positive if <= 0%**
Biler kan se meg, dersom frontlysene treffer meg	18,2%	54,5%	27,3%	27,3%	27,3%	45,4%	**18,1%**
Biler kan se meg i opplyste områder	0%	54,5%	45,5%	0%	54,5%	45,5%	**0%**
Flest fotgjengerulykker skjer i mørket	9,1%	9,1%	81,8%	9,1%	0%	90,9%	**9,1%**

Table J.3: The table shows how group 2's traffic awareness were influence positively in all statements after completing the VR course.

Group 2 (VR)	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Jeg bruker refleks i opplyst område	36,4%	36,4%	27,2%	9,1%	0%	90,9%	**62,8%**
Jeg ser meg for før jeg krysser veien i mørket	0%	0%	100%	0%	0%	100%	**0%**
Refleks kan gå ut på dato	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
Jeg ser meg for, før jeg krysser veien i opplyst område	0%	0%	100%	0%	0%	100%	**0%**
Jeg bruker refleks når det er mørkt	9,1%	36,4%	54,5%	0%	0%	100%	**45,5%**
These statements are positive if they disagree.							**Positive if <= 0%**
Biler kan se meg, dersom frontlysene treffer meg	27,3%	54,5%	18,2%	36,4%	45,4%	18,2%	**-9,1%**
Biler kan se meg i opplyste områder	9,2%	45,4%	45,4%	0%	81,8%	18,2%	**-18,2%**
Flest fotgjengerulykker skjer i mørket	18,2%	9,1%	72,7%	27,3%	18,2%	54,5%	**-18,2%**

Table J.4: The table shows the subjects' opinion on simulators when applied in the driving education. The majority of candidates have a positive view on this as a learning tool.

Statement	**Uenig**	**Litt enig**	**Enig**
Jeg føler at det er bedre å gjennomføre kurset inne	15,4%	46,2%	38,4%

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Table J.4 – *Continued from previous page*

Statement	**Uenig**	**Litt enig**	**Enig**
Jeg ville heller gjort dette inne hvis jeg kunne	15,4%	23,1%	61,5%
Jeg synes at kurset var spennende	0%	0%	100%
Jeg følte at det alltid var lett å få med seg hva som skjedde	7,7%	30,8%	61,5%
Jeg har troen på at dette kan brukes til å gjennomføre kurset hele året	7,7%	30,8%	61,5%
Hvis mulig, hadde jeg heller gjennomført kurset tettere opp mot førerprøven hvor jeg kunne få kjøre selv	15,4%	38,5%	46,1%
Jeg synes at det å kjøre med to elever sammen er en god løsning	23,1%	23,1%	53,8%
Jeg følte at simulatoren gikk igjennom læringsmålene for fort	69,2%	7,7%	23,1%

Table J.5: The subjective evaluation of the VR course for the control group. They learned equal to or more than they expected in almost all listed learning goals.

Control Group (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Få innsikt i realistiske situasjoner	0%	0%	100%	0%	0%	100%	**0%**
Hvordan ulykker oppstår i mørket	0%	0%	100%	0%	0%	100%	**0%**
Risikoforståelse i mørket, kontra dagslys	0%	0%	100%	0%	0%	100%	**0%**
Bruk av refleks	0%	0%	100%	0%	0%	100%	**0%**
Bruk av lys i mørket	0%	0%	100%	0%	0%	100%	**0%**
Forskjellen på bruk/ikke bruk av refleks	0%	50%	50%	0%	0%	100%	**50%**
Hvordan siktstrekningen er i mørket	0%	50%	50%	0%	0%	100%	**50%**
Hvordan en ferdes på veien i mørket	0%	0%	100%	0%	0%	100%	**0%**

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Table J.5 – *Continued from previous page*

Control Group (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Hvordan bilen skal plasseres	0%	50%	50%	0%	50%	50%	**0%**
Hvilken faktor farten har i mørket	0%	50%	50%	0%	0%	100%	**50%**
These statements are not a part of the night driving.							**Positive if <= 0%**
Bruk av varseltrekanten	0%	0%	100%	0%	100%	0%	**-100%**
Hvordan man kan kjøre fort i mørket	50%	50%	0%	50%	50%	0%	**0%**
Bruk av lys i dagslys	0%	100%	0%	50%	50%	0%	**-50%**
Lære om ulike lys på bilen	0%	0%	100%	0%	50%	50%	**-50%**

Table J.6: The subjective evaluation of the traditional night driving course for group 2. They learned more than they expected in 7 out of 14 statements.

Group 2 (RL)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Få innsikt i realistiske situasjoner	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
Hvordan ulykker oppstår i mørket	0%	9,1%	90,9%	0%	27,3%	72,7%	**-18,2%**
Risikoforståelse i mørket, kontra dagslys	0%	18,2%	81,8%	0%	9,1%	90,9%	**9,1%**
Bruk av refleks	0%	9,1%	90,9%	0%	0%	100%	**9,1%**
Bruk av lys i mørket	0%	18,2%	81,8%	0%	9,1%	90,9%	**9,1%**
Forskjellen på bruk/ikke bruk av refleks	9,1%	0%	90,9%	0%	0%	100%	**9,1%**
Hvordan siktstrekningen er i mørket	0%	27,3%	72,7%	0%	18,2%	81,8%	**9,1%**

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Table J.6 – *Continued from previous page*

Group 2 (RL)	Expectations			Subjective evaluation			Positive if >= 0%
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Hvordan en ferdes på veien i mørket	0%	18,2%	81,8%	9,1%	27,3%	63,6%	**-18,2%**
Hvordan bilen skal plasseres	0%	27,3%	72,7%	18,2%	54,5%	27,3%	**-45,4%**
Hvilken faktor farten har i mørket	0%	9,1%	90,9%	9,1%	18,2%	72,7%	**-18,2%**
These statements are not part of the night driving.							**Positive if <= 0%**
Bruk av varseltrekanten	9,1%	18,2%	72,7%	0%	18,2%	81,8%	**9,1%**
Hvordan man kan kjøre fort i mørket	27,3%	18,2%	54,5%	45,4%	27,3%	27,3%	**-27,3%**
Bruk av lys i dagslys	9,1%	36,4%	54,5%	18,2%	36,4%	45,4%	**-9,1%**
Lære om ulike lys på bilen	0%	36,4%	63,6%	0%	9,1%	90,9%	**27,3%**

Table J.7: The subjective evaluation of the VR course for group 2. They learned more than they expected in 10 out of 14 statements.

Group 2 (VR)	Expectations			Subjective evaluation			Positive if >= 0%
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Få innsikt i realistiske situasjoner	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
Hvordan ulykker oppstår i mørket	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
Risikoforståelse i mørket, kontra dagslys	0%	0%	100%	0%	9,1%	90,9%	**-9,1%**
Bruk av refleks	9,1%	18,2%	72,7%	0%	0%	100%	**27,3%**
Bruk av lys i mørket	0%	9,1%	90,9%	0%	9,1%	90,9%	**0%**
Forskjellen på bruk/ikke bruk av refleks	0%	9,1%	90,9%	0%	0%	100%	**9,1%**

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Table J.7 – *Continued from previous page*

Group 2 (VR)	**Expectations**			**Subjective evaluation**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Hvordan sikt-strekningen er i mørket	0%	18,2%	81,8%	0%	18,2%	81,8%	**0%**
Hvordan en ferdes på veien i mørket	0%	18,2%	81,8%	0%	27,3%	72,7%	**-9,1%**
Hvordan bilen skal plasseres	9,1%	36,4%	54,5%	9,1%	18,2%	72,7%	**18,2%**
Hvilken faktor farten har i mørket	0%	9,1%	90,9%	0%	18,2%	81,8%	**9,1%**
These statements are not part of the night driving.							**Positive if <= 0%**
Bruk av varseltrekanten	9,1%	18,2%	72,7%	9,0%	45,5%	45,5%	**-27,2%**
Hvordan man kan kjøre fort i mørket	36,4%	9,1%	54,5%	27,3%	9,1%	63,6%	**9,1%**
Bruk av lys i dagslys	18,2%	54,5%	27,3%	27,3%	45,4%	27,3%	**-9,1%**
Lære om ulike lys på bilen	0%	9,1%	90,9%	0%	9,1%	90,9%	**0%**

Table J.8: The table shows a comparison between the subjective evaluation from each group after completing their first course. The VR course appears to be non-inferior to the RL course in the majority of statements.

Subjective evaluation	**Net difference for each course**			**Positive for VR course if >= 0%**	
Statements	**CG (VR) Diff.**	**G2 (RL) Diff.**	**G2 (VR) Diff.**	**CG (VR) - G2 (RL)**	**G2 (VR) - G2 (RL**
Få innsikt i realistiske situasjoner	0%	-9,1%	-9,1%	**9,1%**	**0%**
Hvordan ulykker oppstår i mørket	0%	-18,2%	0%	**18,2%**	**18,2%**
Risikoforståelse i mørket, kontra dagslys	0%	9,1%	-9,1%	**-9,1%**	**-18,2%**
Bruk av refleks	0%	9,1%	27,3%	**-9,1%**	**18,2%**
Bruk av lys i mørket	0%	9,1%	0%	**-9,1%**	**-9,1%**

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Table J.8 – *Continued from previous page*

Subjective evaluation	**Net difference for each course**			**Positive for VR course if >= 0%**	
Statements	**CG (VR) Diff.**	**G2 (RL) Diff.**	**G2 (VR) Diff.**	**CG (VR) - G2 (RL)**	**G2 (VR) - G2 (RL**
Forskjellen på bruk/ikke bruk av refleks	50%	9,1%	9,1%	**40,9%**	**0%**
Hvordan sikt-strekningen er i mørket	50%	9,1%	0%	**40,9%**	**-9,1%**
Hvordan en ferdes på veien i mørket	0%	-18,2%	-9,1%	**18,2%**	**9,1%**
Hvordan bilen skal plasseres	0%	-45,4%	18,2%	**45,4%**	**63,6%**
Hvilken faktor farten har i mørket	50%	-18,2%	-9,1%	**68,2%**	**9,1%**
These statements are not part of the night driving.				**Positive for VR course if < 0%**	
Bruk av varseltrekanten	-100%	9,1%	-27,2%	**-109,1%**	**-36,3%**
Hvordan man kan kjøre fort i mørket	0%	-27,3%	9,1%	**27,3%**	**36,4%**
Bruk av lys i dagslys	-50%	-9,1%	-9,1%	**-40,9%**	**0%**
Lære om ulike lys på bilen	-50%	27,3%	0%	**-77,3%**	**-27,3%**

Table J.9: The table shows the evaluation of the simulator approach for the control group. The CG seems to be satisfied with the simulator approach.

CG, Klarte kurset å lære deg..	**Nei**	**Ja**
..hva som er god og dårlig siktstrekning?	0%	100%
..siktstrekningen som vist med antall meter sikt langs veien?	0%	100%
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte?	0%	100%
..et godt bilde på hvordan lysene på en bil skal virke?	0%	100%
..når møtende bil har feil bruk av lys?	50%	50%
..hvordan lysene skal brukes ved kjøring?	0%	100%
..et godt inntrykk av hvordan farten skal tilpasses mørket?	0%	100%

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Table J.9 – *Continued from previous page*

CG, Klarte kurset å lære deg..	**Nei**	**Ja**
..et godt inntrykk av bilens plassering i mørket?	0%	100%
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket?	0%	100%
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør?	0%	100%
..risikoforskjellen på når en ferdes i mørke, kontra dagslys?	0%	100%

Table J.10: The table shows the evaluation of the simulator, and the traditional approach for group 2. The simulator approach is non-inferior to the traditional approach for the majority of statements.

Evaluation of the course approach	**Traditional**		**Simulator**		**Positive if >= 0%**
Klarte kurset å lære deg..	**Nei**	**Ja**	**Nei**	**Ja**	**Diff.**
..hva som er god og dårlig sikt-strekning?	9,1%	90,9%	0%	100%	**9,1%**
..siktstrekningen som vist med antall meter sikt langs veien?	18,2%	81,8%	0%	100%	**18,2%**
..forskjellen på bruk/ikke bruk av refleks av fotgjengere på en god måte?	0%	100%	0%	100%	**0%**
..et godt bilde på hvordan lysene på en bil skal virke?	9,1%	90,9%	0%	100%	**9,1%**
..når møtende bil har feil bruk av lys?	18,2%	81,8%	18,2%	81,8%	**0%**
..hvordan lysene skal brukes ved kjøring?	9,1%	90,9%	0%	100%	**9,1%**
..et godt inntrykk av hvordan farten skal tilpasses mørket?	36,4%	63,6%	9,1%	90,9%	**27,3%**
..et godt inntrykk av bilens plassering i mørket?	36,4%	63,6%	9,1%	90,9%	**27,3%**
..et godt inntrykk av hvorfor møteulykker kan oppstå i mørket?	27,3%	72,7%	0%	100%	**27,3%**
..hvordan man bør ferdes på en trygg måte i mørket som fotgjenger og sjåfør?	18,2%	81,8%	9,1%	90,9%	**9,1%**
..risikoforskjellen på når en ferdes i mørke, kontra dagslys?	0%	100%	9,1%	90,9%	**-9,1%**

Table J.11: Opinion on VR simulator as a learning tool. The simulator is considered positive as a learning tool, based on the majority of statements.

All	**Before driving**			**After driving**			**Positive if >= 0%**
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
Man kan lære mer fra mørkedemo i VR simulator enn det som gjøres ute	30,8%	46,2%	23,0%	15,4%	38,4%	46,2%	**23,2%**
Jeg opplevde at simulatoren var realistisk.	0%	46,2%	53,8%	0%	23,1%	76,9%	**23,1%**
VR simulatoren kan erstatte deler av den obligatoriske kjøreopplæringen.	23%	38,5%	38,5%	7,7%	38,5%	53,8%	**15,3%**
VR burde erstatte all obligatorisk kjøreopplæring.	61,5%	23,1%	15,4%	61,6%	30,7%	7,7%	**-7,7%**
Jeg lærer mer av VR simulator fordi jeg hadde mer oversikt over omgivelsene.	15,4%	30,8%	53,8%	15,4%	61,5%	23,1%	**-30,7%**
Jeg klarte å leve meg inn i verdenen når jeg var i simulator.	0%	30,8%	69,2%	7,7%	23,1%	69,2%	**-7,7%**
Jeg opplevde at farten var den samme som fartsmåleren viste.	15,4%	30,8%	53,8%	7,7%	38,5%	53,8%	**7,7%**
I simulatoren følte jeg at jeg satt i en ekte bil.	15,4%	30,8%	53,8%	7,7%	30,8%	61,5%	**7,7%**
Det var gøyere å kjøre i simulator enn å være med på tradisjonell (ute) mørkedemo.	7,8%	46,1%	46,1%	0%	46,1%	53,9%	**7,8%**

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Table J.11 – *Continued from previous page*

All	Before driving			After driving			Positive if >= 0%
Statement	**Uenig**	**Litt enig**	**Enig**	**Uenig**	**Litt enig**	**Enig**	**Diff.**
These statements are positive if they disagree.							**Positive if <= 0%**
VR teknologi har ingen fremtid i kjøreopplæring.	92,3%	0%	7,7%	92,3%	0%	7,7%	**0%**
VR simulatoren gir ikke mer utbytte enn andre bilsimulatorer.	15,4%	53,5%	30,1%	61,6%	30,7%	7,7%	**-46,2%**
Det var ubehagelig å bruke simulatoren.	61,5%	38,5%	0%	76,9%	15,4%	7,7%	**-7,7%**

Table J.12: The table shows reported symptoms related to simulator sickness. No cases of simulator sickness was reported.

Hvilke symptomer hadde du under- eller etter simulator opplevelsen?	**Nei**	**Ja**
Svimmelhet	100%	0%
Hodepine	100%	0%
Kastet opp	100%	0%
Kvalme eller uggenhet	100%	0%
Kaldsvette	100%	0%
Øyeverk, vondt i øyene eller sliten i øynene	100%	0%
Ekstra trøtthet	100%	0%
Annet	100%	0%

Thomas André Skaaheim

Towards a driving license in VR: assisting young drivers learning safe driving in Norway using VR technology

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