Master's thesis

NTNU
Norwegian University of Science and Technology

Stian Sørli

Towards a driving license in VR

Assisting young drivers learning safe driving in Norway using VR technology

Master's thesis in Informatics
Supervisor: Simon McCallum and Ekaterina Prasolova-Førland
July 2020

NTNU
Norwegian University of Science and Technology

Stian Sørli

Towards a driving license in VR

Assisting young drivers learning safe driving in Norway using VR technology

Master's thesis in Informatics
Supervisor: Simon McCallum and Ekaterina Prasolova-Førland
July 2020

Norwegian University of Science and Technology

NTNU
Norwegian University of
Science and Technology

Abstract

Getting your driving license requires practice. With the increased popularity of Virtual Reality and gamification, can we combine these elements and make a helpful learning tool?

This report documents the development of a Virtual Reality application intended to aid Norwegian drivers in practicing safe driving. The report details the entire process from problem definition, ideation, through testing and showing final results after testing and consulting with industry experts. The process has followed a human-centered design approach, making use of iterative development and rapid user testing. A literature review has been done to evaluate where the current state of the art is, and what makes Norwegian driving conditions unique and interesting. We have looked at the use of low-cost Virtual Reality hardware, and how an application such as this one can also help with remote learning, as it becomes a more desirable thing. Another topic has been how such an application can effectively become a learning tool, using concepts from gamification The game we have developed places players in the middle of a dark Norwegian country road, where they must show proficiency in safe driving by being aware of hazards and following traffic rules.

Any conclusions on the application's usage as an effective learning tool are hard to draw from our results. More testing is valuable to find out what currently works and what doesn't. We present a novel idea using low-cost hardware, and suggest future improvements by designing more towards repetitive training.

Sammendrag

Veien til førerkort er lang, og krever mye trening. I en verden der det virtuelle tar over mer og mer, sammen med økt interesse for spillopplevelser, kan vi kombinere disse til et læringsverktøy?

Denne rapporten dokumenterer utviklingen av en Virtual Reality applikasjon ment for å hjelpe norsk ungdom med øvelseskjøring. Rapporten omhandler hele prosessen fra definisjon, idemylidring og gjennom testing og sluttresultater, med innblikk fra eksperter. Prosessen has fulgt en menneske-sentrert design metodologi, og vi har tatt i bruk iterativ utvikling og hyppig brukertesting. Vi har sett på literaturen innenfor fagfeltet for å drøfte hvor feltet er, hva som mangler, og hva som gjør norske kjøreforhold unike. Vi har sett på bruken av rimelig Virtual Reality-utstyr, og hvordan vår applikasjon kan hjelpe med fjernlæring, nå som det blir mer og mer attraktivt. Et tema som har blitt tatt opp er hvordan en slik applikasjon kan effektivt bli et læreverktøy, ved bruk av konsepter som gamification. Spillet vi har utviklet kaster spillere i midten av en mørk norsk landevei, og spillerne må vise sine ferdigheter innenfor trygg mørkekjøring ved å legge merke til farer i bilveien og å følge trafikkregler.

Det er vanskelig å trekke noen tydelige konklusjoner angående applikasjonens læreutbytte utifra våre resultater. Mer testing er nødvendig før vi kan finne ut hva som fungerer bra og hva som ikke fungerer. Vi tilbyr en ny og unik ide ved bruk av rimelig utstyr og fokus på førernes syn, og foreslår videreutvikling ved å designe applikasjonen mot mengdetrening.

Preface

I want to preface by declaring that any content inside this masters thesis has been made by me and me alone, following ethical guidelines given by NTNU. The text has been written by me and has not been plagiarised.

This report has been made for a masters thesis at the Institute of computer science at the Norwegian University of Science and Technology (NTNU) and is the concluding work after five years of studying in Trondheim. This thesis has been made in the autumn and spring of 2019/2020, and has been made in collaboration with the research group IMTEL at the Department of Education and Lifelong Learning.

This report has been made alongside a software project, the implementation of which is detailed in the report. We believe the development of the software is just as much of a part of this project as this report.

I want to give thanks to all the kind souls who helped with testing the application, as well as the helpful driving instructors from Wright Trafikkskole. Additionally I want to thank my supervisors Ekaterina Prasolova-Førland and Simon McCallum, for aiding me through this challenging project. I want to thank everyone else at IMTEL, Jose Garcia and Mikhail Fominykh, and all my fellow students making amazing VR solutions for the future.

Final thanks goes to my parents and my girlfriend, for helping me out when I needed it. Another thanks to our family cat Pondus, who passed away during the time of this project. Rest in peace, little buddy.

Contents

Figures

Tables

Chapter 1

Introduction

The introductory chapter will outline the backdrop of this report. The chapter will describe the context behind this project, what its purpose has been and what we have created.

1.1 Context

Norway is a country which receives little sunlight during the winter months, combined with an abundance of wildlife, this can pose as a considerable risk when driving. In order to obtain a Norwegian driving license one must attend a special course to be licensed to drive in traffic during winter. Being able to handle the risks that come with night driving is one of the core parts of the driver curriculum.

The Norwegian government, together with the Norwegian Public Road Authority has set an ambition towards zero deaths or serious injuries in traffic[1]. In order to reach this, they are interested in finding new and innovative ways of increasing safety and improving learning. Ever since this ambition became official policy results have been increasingly positive with fewer and fewer lethal accidents, citing effective collaboration with organisations, industry and educational facilities as deciding factors.

Since night driving is a mandatory part of the driver curriculum, it cannot actually be completely replaced by simulator training. More research on this topic is needed to prove the efficacy and value of simulator use. We want to contribute to this research by showing that low-cost VR equipment can be used to help people learn night driving.

Using VR technology to aid in learning things is not an original concept, and it has been used in many studies before, with regards to traffic learning. VR has shown good results in practising otherwise risky tasks in a safe environment, and has been proven to be a good tool for learning.

[1] https://www.vegvesen.no/fag/fokusomrader/trafikksikkerhet/nullvisjonen

1.2 Purpose

The aim of this project has been to find a new and inventive use of VR technology to aid in driver's education. Knowledge gained from this project can be used for future research, and the prototype developed can be used for further data gathering and development.

This project has focused on the specific intersection between young drivers, night driving and VR technology. To see if night driving can be taught to aspiring drivers using simple and accessible low-cost VR technology.

We want to use tools from game design, interaction design and software development to make a statement on how we can solve and improve the current environment of night driving learning.

Previous research in Norway on this topic has shown positive results, but there is an interest for more conclusive research on the topic. Examples of this are the study "Å kjøre norsk"[1] (To Drive Norwegian), which states that driving simulators are a good supplement to the Norwegian driving curriculum, and Sætren's Simulator versus traditional training study[2], in which simulator use shows increased learning for students doing the night driving course. Sætren also brings up a lot of relevant points in their 2018 study[3], where they elaborate on challenges in the field of driving simulators for driver education.

Following a problem definition period, we came up with several suitable problems and opportunities we were interested in pursuing. The problems and opportunities we identified and wanted to address are the following:

- VR is good for learning, can the same be applied to learning traffic?
- Gamification is a useful tool for capturing a younger demographic
- High risk situations can be seen and "played" in a safe space
- Is a wheel/pedal setup necessary, or are VR controllers good enough?
- Remote learning in the digital age

As we kept going and made the framework of this project, we changed these problems into research questions. The specific research questions we have set out to answer are the following:

- **How can we teach young drivers in Norway safe night driving using VR technology?**
- **How can we use gamification in order to learn safe driving?**
- **Can a VR application help with remote learning of safe driving**

1.3 Methodology

We have been using the design and creation research strategy[4] as a core strategy, focusing on the design and development of an IT artefact aimed at answering the aforementioned RQs. The artefact has then been put through testing to evaluate whether or not it fulfils the requirements set and whether it does its job adequately.

The main idea is to develop a prototype of a serious VR game allowing players to immerse themselves in the night driving experience and train on how to drive properly, following Norwegian traffic situations and conditions. By using game elements and mechanics, we can turn an immersive experience into an interactive and engaging learning tool.

Developing this prototype lets us test various game mechanics and evaluate them against learning outcomes to see which mechanics have merit and which are not useful for learning night driving.

The implementation has followed an iterative development model, as described by the book Agile and iterative development: a manager's guide.[5] Iterative development follows a pattern of improving software gradually, changing plans depending on feedback received between development iterations. This is explained in more detail in chapter 3. Each iteration of development is detailed in chapter 4.

The artefact has been tested against end users and experts from the field of driver's education, using user testing, questionnaires and interviews as primary data gathering methods. The results of the testing are shown in chapter 5.

A full description of the process, including tools and methods chosen is described in chapter 3.

1.4 Tangible artefact

The outcome of this project, alongside this report, is a virtual reality serious game which emulates the experience of nighttime driving in Norway, using gamification elements to make it a tool for learning instead of just entertainment.

Players are intended to be put through emulated situations and perform actions in a gameful environment which can help them learn how to keep stay attentive during night driving, avoiding dangerous situations with wildlife and managing challenging situations on ice and on curvy, tight Norwegian roads.

The game consists of two levels. The first is a tutorial level to ease players into the virtual experience and to teach them the controls of the game. The tutorial gives the players instructions introducing one gameplay element at a time, increasing in intensity and difficulty. A full textual walk-through of the tutorial can be found in Appendix D.

The second level is a full-length level intended to test the player's knowledge and skill. The player drives through a 5.7km long course, designed to represent Norwegian rural roads. The player drives along the road, focusing on being aware of their surroundings and keeping an eye out for danger. The game rewards the player for safe driving and deducts points for sloppy or unsafe driving. When the player reaches the end, they get an overview of their performance, which they can compare with their friends.

The game has the potential to be added to by developing more levels, where the player can be tested in different conditions and situations. The game is rather flexible, and one can easily develop own levels to run for the game. The interlocking game mechanics connected to the player, car and hazards can be used in other levels and environments without porblem.

The game also offers a drifting mode for daring players who want to take a break from learning and play purely for fun instead.

A video walkthrough of the game can be found here:
https://drive.google.com/drive/folders/1CVIZaoCH6vcxIbczlOOWVeJBfwUjtffw

An executable build of the final prototype can also be found at that location. Links to more material can be found in appendix E.

From this point forward, when this report mentions the "game", "prototype" or "application", it is referencing this artefact.

1.5 Covid-19

By the time of writing, the Covid-19 pandemic is still ongoing, and much of society is still staying locked. It broke out after this project had started, and as our university had to be closed down, we suffered consequences.

Notably, we were very limited by testing, as it became impossible to run in-person tests.

Implementation also became a bit halted due to having to work from home. It became a lot harder to communicate within our community of practice, IMTEL. Where we would previously run smaller tests on other students and share feedback on each other's projects, we now couldn't even meet.

We had intended to do focused testing on high school students, but we had to instead rely on remote testing. This is described in further detail in chapter 5.

Chapter 2

Background and research methods

This chapter describes the full context around the project alongside existing research. This chapter aims to make you understand the concepts of VR, games for learning and what other studies precede this. We will describe the current state of the art.

2.1 Virtual Reality

Ever since the first Oculus Rift launched in 2012, the popularity of Virtual Reality has skyrocketed. Today, it has flourished into a large industry with new equipment commercially available every year alongside a surge of video games and software developed specifically for virtual reality. It is still a developing technology, and faces many challenges, especially within the field of accessibility and adverse health effects.

Generally, when one says "Virtual Reality", they mean VR headsets, or Head Mounted Display (HMD) devices such as the Oculus Rift or HTC Vive. Though there are more kinds of virtual reality, including systems making use of monitors and projectors. Similarly, there are different forms of interacting within the virtual world. One might have a large room-scale application which tracks your movements, or an instrument cluster replicating the one found inside some machinery, such as an aeroplane.

The reasons for using virtual reality are twofold. It gives people a bigger sense of immersion, which can have all kinds of benefits such as improved learning capabilities[6] and increased empathy[7]. Virtual reality also allows people to attempt things they could never do before, at least not without significant risk. In VR you can pilot a stunt plane or experience the bottom of the ocean from the safety of your office.

Figure 2.1: Three commercially available HMDs, Oculus Rift, HTC Vive and Acer Microsoft Mixed Reality headset.

Figure 2.2: A cockpit of a flight simulator. The monitors show a virtual environment.

2.1.1 Immersive Technologies

Immersive technologies is a catch-all term for technologies that blend the borders between virtual space and reality, most notably eXtended Reality (XR) technologies, which encompass both VR and Augmented Reality (AR). Franklin Institute defines that VR "implies a complete immersion experience that shuts out the physical world.", whereas AR "adds digital elements to a live view often by using the camera on a smartphone."[8]

Whereas VR allows full immersion inside a fully virtual world, AR lets you combine the real world with the virtual world, by placing objects on your tables, changing the colours of your walls or letting you catch virtual monsters in your backyard. This makes AR and VR different tools for different problems. Many AR applications build around the idea of analysing and reviewing a virtual object in the real world, making use of the virtual element to test transformations and see the object from a new angle. A paradigm that has become rather popular within AR is the digital twin, where you have a digital recreation of a physical object. Using AR you can for example overlay the digital recreation on top of the real object, and receive information about the physical object by interacting with the digital twin.

2.1.2 VR and training

VR technology has long been employed to enhance learning, in fact one of the earliest certified VR technologies was a flight simulator developed by the US airforce at the Wright-Patterson airbase in the 1960s[9]. Ever since, VR has been used for training in complex fields such as fire simulation and evacuation practice[10], where people can practice life-threatening situations without putting themselves at any physical risk. VR has also been applied to professional training, as used by Walmart for training their employees.[11] VR has also been shown to help with drivers education before.[12] VR as a training tool has been shown to improve training outcomes within the field of rehabilitating stroke patients[13], citing factors such as improved visual attention and immersion as the primary causes. These factors are both key components of VR experiences, and highlight that the strengths of the technology can be utilized for learning..

IMTEL at NTNU[1] has become a dedicated research group and community of practice for using XR technology for learning and training purposes. Several VR games and experiences have been developed and found success from there, primarily focusing on giving an insight in new job experiences. Examples include the fields of windmill engineering and fish factory operators.

[1] https://www.ntnu.edu/ipl/imtel

In the context of our project, virtual driving provides a safe, virtual place to practice driving. One can be placed in what would otherwise be dangerous situations without any danger to oneself. Being able to go through such situations can be useful in dangerous situations, as it gives necessary practice, confidence and teaches decision-making.

2.1.3 Immersion

Immersion is an objective measure of technology, Slater describes immersion as "a description of a technology, and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant."[14]

Slater brings up the core ideas of inclusive, extensive, surrounding and vivid illusions, and explains them as such: "Inclusive (I) indicates the extent to which physical reality is shut out. Extensive (E) indicates the range of sensory modalities accommodated. Surrounding (S) indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field. Vivid (V) indicates the resolution, fidelity, and variety of energy simulated within a particular modality (for example, the visual and color resolution)"

All of these illusions are important to keep in mind when developing VR experiences. By making good use of sound design, environmental design and even haptic feedback, one can help reach a higher level of immersion by improving these illusions.

Immersion has shown to improve empathy and learning conditions when performing memorisation tasks[15] in gamified systems. Immersion brings with it a greater sense of presence, more explained in section 3.3.1, which often equates to a better sense of self in the virtual space.

2.1.4 Interaction

How the player interacts within a virtual experience changes a lot for the experience. Different modes of inputs can serve different purposes. Some rely on abstractions, such as menus and teleportation. There are even applications in which one can grab the entire world and drag it around with their hands. These kinds of abstractions are good for simplifying otherwise precise and complex navigation systems, especially since many might be familiar with them from previous software interactions.

Interaction ties in with immersion and with game design. Making decisions for how a player is interacting with the game also means making choices inside the gameplay.

The primary decisions we would have to make are decisions on how the player will interact with their surroundings. As the player is situated inside a car, interactions will be similar to those you could perform inside a real car. Examples include gas and brake pedals, steering, turn signals, climate controls and enabling the windscreen wipers. In a VR game, there are multiple ways to solve these. They can be relegated to simple button presses or the player can be forced to do more invested inputs which more accurately represent their real life counterpart. Consider the difference between turning the steering wheel using a joystick compared to reaching out to grab it and turning it around manually.

2.1.5 Motion sickness and cybersickness

Cybersickness, also known as Visually Induced Motion Sickness, or sometimes known as VR-sickness, is one of the largest issues faced by VR developers and players alike. Developers aim to reduce cybersickness as much as possible, while still wanting to deliver exciting experiences. For some players, cybersickness is a reason to stay away from VR experiences as a whole.

The most common effects of cybersickness include the following:[16]

- Eye strain
- Headache
- Pallor
- Sweating
- Dryness of mouth
- Fullness of stomach
- Disorientation
- Vertigo
- Ataxia
- Nausea
- Vomiting

There are multiple theories as to why cybersickness occurs, the sensory conflict theory, poison theory and postural instability theory.

The sensory conflict theory is the most widely accepted of the theories, and is based on the premise that your vestibular and visual senses receive conflicting information[17], as in your eyes perceive that you are moving, but your body does not perceive any motion through the other senses. The expectation of the visual stimuli conflicts with the vestibular sense, and you may feel cybersickness.

Detractors of the sensory conflict theory point out the lack of predictive power the theory has, one cannot predict whether or not cybersickness occurs in a certain situation, nor how severe it may be. Nor does it account for why some people are affected by cybersickness and some are unaffected. Finally, the theory also doesn't actually explain why such a conflict has the effects it has.

The poison theory looks at motion sickness and cybersickness from an evolutionary perspective.[18] The theory believes that the physiological effects we can feel in VR from the vestibular and visual systems, are similar to the ones we experience when ingesting poison. This causes a warning system inside the body to react, and results in nausea, sweating and vomiting, in order to rid the body of the poison.

Similarly to the sensory conflict theory, there is little predictive power, there is no telling who may get it or when someone experiences cybersickness. The theory is also rather difficult to verify.

The final main theory is the postural instability theory. The postural instabilty theory states that one of humans' primary goals in life is to maintain postural stability in their environment[19], or keeping their balance. LaViola brings up the example of walking on ice versus walking on concrete in their paper[16] "In general, people walk on concrete differently than they do on ice, and if someone tries to walk on ice as they do on concrete, they will usually fall down. However, the natural reaction to walking on ice is to change the walking pattern so as to maintain postural stability." Following, the theory states that motion- and cybersickness is a result of prolonged exposure of postural instability.

Despite the difference in theories, there are many common elements of VR experiences which can cause cybersickness. Some such factors, such as flicker and lag, are not very relevant on current VR hardware, unless your VR software is very poorly optimised. Other factors which are more relevant should be mitigated as much as possible.

Using a HMD instead of a monitor for a driving simulation has shown to display equal learning potential, but it can come at the cost of increased cybersickness[20], although technical improvements in hardware specifications has increased the refresh rates and tracking accuracy of HMDs which drastically reduce cybersickness. There is still some definite risk of cybersickness. The player will be moving a lot in cyberspace without moving their own body.

Thankfully, we can reduce the likeliness of cybersickness by optimising our design. Giving players control over their own motion has been proven to reduce cybersickness[21], this is also believed to be linked with the phenomena of passengers becoming motion sick when drivers don't[22]. We can say we want our players to really feel like drivers instead of passengers in our game. This phenomena has been shown to stay true in VR driving as well.[23]

Other relevant factors are tied to movement of the player in VR. If a player experiences sudden and unexpected movements, it has a higher chance of causing cybersickness. Another prime cause is rotation among the roll-axis.[24] Experiments have also shown that blurring the area in the player's outer field of view can reduce chances of cybersickness.[25] With these in mind, they should be considered when developing and testing the application.

Despite all these measures to prevent cybersickness, some will still be affected by it. It is highly individual, and parameters such as sex, age, vision impairment and how experienced they are with VR are known to be contributing factors. Even when all is done, some will just be unlucky.

2.2 Norwegian traffic

Norwegian driving conditions pose many risks. Assessing and managing these risks is one of the core learning objectives of the Norwegian driver training system. These risks include the narrow and winding country roads, low light levels in winter, icy conditions, and wildlife hazards. These unique quirks and features make this an interesting area to research and work with.

Young drivers in Norway must complete a theory course to understand the fundamentals of driving and safety in a vehicle. The course is often completed by students who are around the age of 15, and they can get a learner's permit for driving once they turn 16 years old.[2]

Statens Vegvesen has identified young drivers, particularly men under the age of 20, as one of the primary high risk groups in traffic. This high risk is primarily by account of lack of experience and a lack of knowledge of accident patterns in traffic[26], this tells us that young people might want some kind of training method to help prevent this.

2.2.1 The Norwegian Driver Curriculum

The Norwegian driver education consists of four parts, based in the GDE (Goals for Driver Education) matrix, which is considered best practice within the field of driver education.

- Step 1: Basic theory surrounding traffic safety. Night driving course.
- Step 2: Basic driving- and vehicle skills
- Step 3: Driving proficiency, safety course on closed track
- Step 4: Final skills and test, safety course on road

In order to move from any step to the next, the driver has to be evaluated. Only exception of this is going from step 1 to 2, which instead requires you to pass basic theory courses.

Night driving can be found in stages 1 and 2, meaning that our project should be aimed at drivers working on these stages.

2.2.2 Night driving

During the winter season Norway receives little sunlight, and it is compulsory for learning drivers to attend a course to learn safe night driving for their learner's permit to be valid during the winter months.[3] The course encompasses how to use the various lights found on a car and how reflective clothes and badges are important for visibility.

One central idea in the course that is difficult to practice is risk assessment, and the course does not include any firsthand practice of night driving, as the course is often done when you're as young as 15. One problem that may arise is a young driver having forgotten all of these important teachings by the time they actually start driving regularly. This was brought up in interviews with driving instructors.

[2] https://www.vegvesen.no/forerkort/ta-forerkort/ovelseskjoring

[3] https://www.vegvesen.no/en/driving-licences/driver-training/night-driving

One very important takeaway from this course is how to properly dim the lights when meeting other drivers, to avoid blinding them. We felt like this was an interesting aspect of night driving which we could integrate into our application.

2.2.3 Wildlife hazards

Wildlife getting on the road and subsequently being hit by cars can pose a danger on Norwegian roads, especially in the case of larger animals such as moose and reindeer, which can weigh multiple tons, and can cause a lot of physical damage to vehicles and people. According to Vilt og Trafikk, an authority on wildlife and traffic, there are between 5000 and 6000 large deer hit by vehicles on Norwegian roads each year, leading to millions in property damage and potentially fatal accidents.[27] The main bulk of wildlife is hit during the dark winter months, due to the lower light and poorer sight conditions. This was something brought up in preliminary interviews with experts, and became a point of interest to implement in our prototype.

2.3 Gamification

Gamification is the act of integrating elements found in games to other applications and systems, generally this is used to keep user retention and increase engagement, spurring increased learning.[28]

Gamification has become more popular in later times with more and more applications, particularly phone apps and websites making use of gamification. Some are simple loyalty programmes and score systems to validate loyal users as we can see with sellers on eBay, getting a reputability score based on their history. Other applications can integrate complete game systems such as levels, score and achievements, which we can see in the app Duolingo.[4] Duolingo is an app made to teach people new languages, and has shown to be very popular and effective, thanks to their use of gamification.

Humans love to play, we're predispositioned to play, and it's only natural for us to play games. Gamification takes advantage of this to make people engage with material and encouraging desirable behaviour. Games motivate us to do something, either through a tangible reward or a number on the screen, or for the sake of our internal desire to learn, as long as we have the ability to do just that, we want to do it. Gamified systems are often connected to status, displaying leaderboards to compare our performance to our nearest friends or on a worldwide basis.

2.3.1 Motivation

Motivation can be divided into two primary categories, intrinsic and extrinsic motivation. Extrinsic motivation is typically a physical reward, perform an action,

[4] https://www.duolingo.com

receive a piece of candy. For an extrinsic reward system to work, the player must be continuously rewarded, else they will stop playing. Thus, designers of reward systems often implement operant conditioning, as popularized by the infamous skinner box experiment[29], to keep players hooked.

Intrinsic motivation is motivation without any external reward, where you perform desired behaviour for your own betterment or satisfaction instead of a shiny badge. This puts the player in a more healthy mental state when playing and learning.[30]

Since this is a game for learning, we have a strong intrinsic motivation in the players. There is a motivating factor in the player wanting to use the game to achieve their goal of driver competence. Scott Nicholson states that "The feeling of mastery of a skill can drive engagement such that rewards are no longer needed."[31]

In order to drive motivation further, we want to build a score system for the player to evaluate their performance. If the player is driven by their motivation to learn, the score should reflect how well they are doing so they can reflect on their skill. The score judges the player, and as long as they interpret their judgement as fair, the player should approve of it.[32]

Having a score system works as reinforcement for the player. If they see the score go up, they receive positive reinforcement that the action they are performing is desirable. By linking these desirable in-game actions to learning activities, we effectively reinforce the player's learning.

2.3.2 Flow

Flow is a hard-to-define concept tied to game design and progression. Flow is a state a player might enter if a game keeps them properly challenged and entertained. Some define it as "zoning out".[33]

Flow means toeing the line between anxiety and boredom. As a game designer we must give the player enough of a challenge to have them consider new approaches and strategies, which keeps their mind in the game and focused on solving puzzles. However, making it too hard can give the player frustration and anxiety, pulling them out of the experience as they struggle with challenges. There is little more immersion-breaking than having to search up a walkthrough guide to progress.

2.3.3 Serious games

Serious games are a subset of games, where the primary purpose is more than just to entertain. A serious game can give players an interactive experience, make the player learn new skills or even aid as a tool for therapy. Serious games can be new tools to perform learning activities or used as supplements to traditional learning.

Serious games have been used for research in the field of therapy and education of children with Autism Spectrum Disorder. By giving more engaging tasks through the lens of a game, they are able to for example connect with emotions better.[34]

There are also more commercially available serious games, such as Depression Quest[5], a game making good use of traditional game elements to create an experience which makes players empathise with depressed people. Another example is the DragonBox series of games, mobile games for iOS and Android aimed at a young audience to help teach maths.[6]

Some serious games are VR games. By using the advantages brought to us by VR, serious games can gain a new dimension, particularly in fields where immersion and empathy are central. VR serious games have shown higher user satisfaction than other learning methodologies, a point which can justify higher learning rates.[35]

In a study by Pedro Gamito,[36] a VR serious game is developed and evaluated for rehabilitation of stroke patients. The game has patients perform daily activities and tests their orientation and attention. Based on their evaluations, VR systems show results comparable to real-life rehabilitation. Though by using VR there is no physical consequence in case of errors, which can facilitate the patients' rehabilitation as they don't fear any consequences.

2.4 State of the art

2.4.1 Simulator versus traditional training: A comparative study of night driving training

This is a study from 2019 conducted to showcase the value of simulator use in night driving training.[2] The study was done by Nord Universitet in Stjørdal.

Their study compares learning outcomes of simulator use and the current traditional night driving course. As this is a Norwegian study it's highly relevant to us. Their approach is a case study around testing a simulator designed to teach people night driving. In their case study, one group performs the currently common night driving course and another group performs night driving learning using a simulator instead. Their research conclusively shows that the students using a simulator end up having better learning outcomes than those who do not.

In their further work section, they point out how they want to study different scenarios in simulator use for Norwegian driver training. In our case we are also looking at night driving, but using traditional VR equipment instead of a large-scale simulator. In our case we can focus on the user's gaze, as we use VR headsets which can track the head motion, making use of different tools in order to test different scenarios and learning activities. We will also use gamification elements.

[5] http://www.depressionquest.com/dqfinal.html
[6] https://dragonbox.com

2.4.2 Å Kjøre Norsk

This is a Norwegian study conducted by the Institute of Interdisciplinary Studies of Culture at NTNU.[1] The title translates to "To drive Norwegian". The study is a qualitative study reviewing the Norwegian driver's curriculum and aims to reach a conclusion whether simulator training can be a valuable asset for training Norwegian drivers. The study also reflects on how to eventually utilise simulators efficiently in Norway.

The study believes that simulators can have good use in all stages of driver's education, but has a special spot in the first two stages showcased in 2.2.1 where they can be utilised without necessary professional surveillance. There are challenges to face before it can see widespread usage.

One big challenge is the idea of domestication, to move the general public's perception of simulators as huge and complex devices often relegated to professionals towards a more casual and domestic belief that anyone can make use of simulators for their training. This challenge has primarily been overcome by proving to people that simulator training makes for a good supplementary learning tool, but the domestication is still ongoing.

They conclude by mentioning how simulators for training are still considered "in the making", and there is a definite potential in simulators for mass training without professional help, as well as simulators being a good tool for integrating theory and practice into one.

We want to build on this by showing a novel implementation of a driving simulator, one that makes more use of low-cost VR equipment and gamification elements. Our belief is that this system can aid in domesticating driving simulators further.

2.4.3 Gamified virtual reality driving simulator for asserting driving behaviors

This is a study of the development of a gamified virtual reality driving simulator making use of low-cost VR equipment.[37] This study uses a simulation of the driving experience in conjunction with artificial intelligence non-player characters (NPC) to create a realistic driving environment.

Their system observes player's behaviours and judges how well the participants are able to follow directions and rules, and how well they perform potentially challenging manoeuvres. They state that the current state of VR equipment has developed to a point where simulations of dangerous situations for the sake of learning are possible, and giving people a safe environment to test themselves is a good way of testing their skill and learning new skills.

Their approach has been to make a gamified experience in order to appeal to younger drivers, as they are more prone to having traffic accidents. By making them use their system, they can evaluate their performance and learn how to handle these dangerous situations in case they find themselves in a real-life dangerous situation.

2.4.4 Comparing to other products

The following is a list of commercial products, mostly games, comparable, which will make the basis of what we compare this application to.

iRacing

iRacing[7] is an online multiplayer racing game, praised for its realistic simulation. iRacing has since become used to replace physical racing events sponsored by the FIA and Nascar during the Covid-19 pandemic.[8]

iRacing allows for VR support, and supports a wide range of inputs, but not VR controllers. As it is marketed towards serious racing gamers, it is common for them to use steering wheel setups.

The game does not help in learning traffic, but does focus a lot on learning proper racing, so one could arguably say that it is a learning tool.

City Car Driving

City Car Driving[9] is a single-player game. The game offers a multitude of parameters which can be changed to emulate different situations, including left and right-handed driving, regional driving rules and weather conditions.

The game allows for practising many different traffic rules and scenarios, mostly focused on traffic situations involving other drivers. Such as passing cars.

The game can also be used recreationally to just enjoy a drive in a city.

The game does not support a lot of input methods. We couldn't get it working with VR controllers, and had to use a gamepad or keyboard inputs.

Way Simulator

Our third choice goes to any proper full-sized simulator. These come in many shapes and sizes, but have a lot in common. There are huge and complex ones like Ford's VIRTTEX simulator[10], or smaller ones built using commercial components like monitors and USB steering wheels. Typically these are purpose-built for a specific use case and often requires dedicated hardware designed for it. They rarely require any learning to understand, as they are made to emulate real cars. In a realistic example, one should also generally consider the cost of such systems. Though, if we look at this from the user's view, they are not the ones paying for the implementation.

[7] https://www.iracing.com

[8] https://www.theverge.com/2020/3/22/21184192/sim-racing-coronavirus-f1-nascar-iracing-veloce-esports-max-verstappen-lando-norris

[9] https://citycardriving.com

[10] https://www.extremetech.com/extreme/133549-inside-virttex-fords-amazing-driver-distraction-simulator

For a direct example, we will use the Way Traffic School's simulator[11]. It has some interesting properties, such as being focused on learning and it has a local, Norwegian experience.

The simulator lets learning drivers test themselves in several situations, including mundane ones like how to handle a roundabout as well as dangerous risky situations involving wildlife. Their belief is that the simulator lets you try repeating these manoeuvres and practices easier than if you were driving a real car.

	Supported inputs	Learning	Local (Norwegian roads)	Night driving	Multiplayer
iRacing	Steering wheel, gamepad	X		X	X
City Car Driving	Steering wheel, gamepad	X			
Way Simulator	Steering wheel	X	X	X	

Table 2.1: Other commercially available products

While all of the mentioned support VR, the Way Simulator uses screens to project the virtual environment, instead of an HMD.

[11]https://way.no

2.5 Stakeholders

Three primary stakeholders were identified during the research for this project.

- Driving instructors and schools can gain a new tool to help teach aspiring drivers how to drive safely.
- Young people learning how to drive will be the primary end users who can be benefiting by using this tool, they can be defined as our target audience
- Statens Vegvesen, or the NPRA, Norwegian Public Road Administration

Chapter 3

Process and Tools

This chapter will define the development process and outline the considerations done before implementation began. We will show why we made the choices we did regarding both software and hardware, and describe how these choices affect the project's development and limitations.

3.1 Hardware

This section elaborates on the different hardware tools available for our project. We've made some decisions regarding what to use, and we will discuss these choices below.

3.1.1 Commercial HMDs

The newly released Valve Index presents interesting new opportunities for development, particularly its unique Knuckles controllers which have individual finger tracking, making interactions more intuitive. The Valve Index also has 120Hz refresh rate displays, compared to the HTC Vive and Oculus Rift's 90Hz. The Valve Index is difficult to get a hold on, as there is both a high demand, and the suppliers do not sell worldwide. To counteract this, we had to make an effort to make the game work well on any other SteamVR supporting headset. It has been tested and shown to work without issues on the Oculus Rift and HTC Vive headsets. Making it run on as many headsets as possible is also important to promote remote learning.

3.1.2 Peripherals, Controllers vs wheel

When developing a VR experience, there is a conscious choice to make in what peripherals you want your players to use. The most common choice is to stick with the controllers that accompany your HMD. Many earlier VR systems made use of common video game controllers (Gamepads). Some VR experiences require purpose-built custom peripherals, made to emulate and feel like a specific item

Figure 3.1: The Valve Index, a newly released HMD, from Valve

or tool. The release of independent sensors for VR equipment allows for more tracking, they can for example be attached around a player's feet or waist.

In our case, the most relevant alternative is a USB-connected steering wheel and pedal setup. These peripherals are common among dedicated racing game fans. A setup like this does a great job at representing the driving experience, since it has a tactile steering wheel and pedals to press. A downside that comes with this is added costs and accessibility, alongside potential difficulties with implementation and added issues that can come with third party peripherals, such as drivers.

Downsides of choosing the controllers are lack of tactility and that it's not always as intuitive to the player. We believe the positives can outweigh these downsides, especially since we're using the Knuckles controllers from the Index, as shown in figure 3.2. The Knuckles controllers are unique in that they support independent finger tracking. Where other VR controllers have you press a button to grab, the Knuckles controllers simply have you do a grabbing motion to grab. By having less abstraction between grabbing objects and interacting with the environment, it improves immersion and works better than one might assume.

Additionally, we believe the idea of using regular VR controllers is an interesting aspect to research. Does using VR controllers bring with it downsides? Is the lack of tactility a fair trade-off?

3.2 Software tools

Here we will outline what choices were made in regards to what software we'd use. The software chosen has massive implications for the development of the project.

Figure 3.2: Knuckles controllers, highlighting its unique grip,from roadtovr.com

3.2.1 Unity Game Engine

Unity is a popular game engine, primary reasons for that is being free and rather easy to learn, and it has a large surrounding community which is very helpful when you run into issues. Unity also supports VR, and its ease of use for setting up and running VR projects has made it gain popularity among VR developers. Other alternatives include Unreal Engine[1] and Cryengine[2]. Unreal Engine is the more popular of the two, and is often preferred over Unity due to its larger focus on simulation. It was considered as an option over Unity as it could create better looking results, which could be useful for increasing immersion. Unity was chosen over Unreal due to previous experience and knowledge with using Unity. Cryengine is an engine mostly known for its graphical capabilities, and could also be considered for the sake of creating something good looking and immersive, but was scrapped due to low community support.

Choosing Unity as game engine also decides certain other factors for the development. Importantly, development has to be done in C#, an object-oriented programming language. Developing in Unity also however means that development is component-based.

Each component in Unity is a small piece of software with scripts connected to it. The most common component you find is the GameObject, though there are specialised components such as colliders to handle physics and collision.

Using Unity also opens up the ability to use the Unity Asset Store[3], a digital storefront with content from other Unity users. The Unity Asset Store lets us down-

[1]https://www.unrealengine.com/
[2]https://www.cryengine.com/
[3]https://assetstore.unity.com

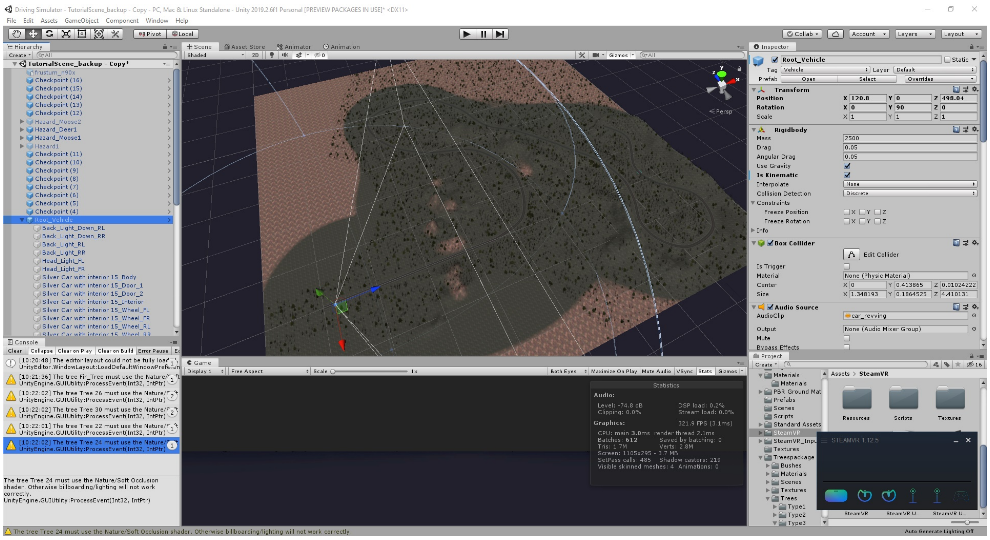


Figure 3.3: The Unity Editor window, here showing the finalised prototype.

load or purchase individual 3D models, textures or scripts to make game development easier. All assets we downloaded are listed in Appendix G.

3.2.2 Unity Collaborate

After Unity had been chosen as a game engine, we made the choice to use Unity Collaborate as our Version Control System. As this was a single person project, we didn't have the constant need to do proper version control, which made more complex systems like GitHub undesirable. Unity Collaborate had a lot of use for cloud storage as the project was worked on from different computers.

3.2.3 SteamVR

SteamVR[4] is a tool created by Valve, creators of Steam and the Valve Index, made to simplify VR development. SteamVR functions as middleware between the hardware, HMD and controllers, and the software, which in our case is the game. SteamVR lets us set up custom control schemes and key bindings for the controllers.

Using SteamVR for your project makes it seamless to make the game run on most HMDs. This is crucial for accessibility and distribution of a VR project. In our case, it made it possible to have people try the game using the HMD they have at home.

SteamVR also offers a library for Unity development, which contains many useful scripts and objects that can work as a boilerplate solution for VR development.

[4]https://store.steampowered.com/app/250820/SteamVR/

3.3 Development process

This section aims to give an insight in the process we chose for the development. We will describe paradigms used, as this is an integral part to the whole process.

3.3.1 Human-centered design and development

Following on the focus of design and creation, as mentioned in chapter 2, the entire process revolves around the development of a single artefact. The artefact in question is a VR application, which comfortably sits in the realm of user experience. Thus a human-centered design philosophy, which has been proven to be useful for VR development[24], has been chosen as a design philosophy.

We've based our design process around Gould and Lewis' principles of design[38] when creating for usability. Their approach note three key principles.

- Early and continual focus on users
- Empirical measurement
- Iterative design

The early and continual focus on users have us always ensuring our application is aimed at our end-users. During problem definition, the players are at the centre, and their needs and wants are integral to the design of the application.

Empirical measurement means that we have the users involved and get data for the application from the users themselves. Recording and analysing their performances and reactions gives us insight in the application's usability.

Iterative design is a cycle of design where you continuously improve the application. When problems are found while user testing, they must be fixed. Thus paradigm is described in more detail below.

Mental models and intuitiveness

According to The VR Book[24], the importance of intuitiveness can be described as "An intuitive interface is an interface that can be quickly understood, accurately predicted, and easily used. Intuitiveness is in the mind of the user, but the designer can help form this intuitiveness by conveying through the world and interface itself concepts that support the creation of a mental model."

The player should easily be able create a mental model in our case, as there is a clear one-to-one mapping between the in-game car interface and a real car's interior. This entails the player already having some knowledge of a car's interior, which is a reasonable assumption to have.

In some cases, where information is not easily available, the addition of text helps convey the message. For example the gear shift lever in our game is marked with text displaying what gear the player is in. The lack of tactility makes it harder to keep track of what gear you are in, so this text helps a lot.

Awareness and presence

Presence is closely tied to immersion, and can be roughly defined as the player having situational awareness of where they are in the virtual world, as opposed to the real world.[24] As the player becomes more immersed in the world, they feel their own presence in the virtual space. Importantly in our project are making the player aware of where they are, what space they are occupying and where they are heading. In addition, we want to make sure the player gains awareness of how well they are performing, in relation to the gamification aspect.

With the player seated in a vehicle, we wanted to make sure the player feels as if they are sitting there, with familiar elements such as a steering wheel, gear stick and fog light stalk. With these interactive elements, it is important to make them stand out enough to communicate to the player that these are items to interact with, yet they shouldn't stand out so much that it detracts from the immersive experience. A common solution to this is to give the elements a high-visibility outline when the player moves their hand close.

For the player to be aware of their movement, small but meaningful elements were added. First off, the player has a speedometer constantly displaying their current speed in km/h. Additionally, the position of the steering wheel represents the steering angle of the car. In other words, if the steering wheel is rotated clockwise, the car will be steering to the right. There is also an engine sound coming from the car, increasing in volume and pitch as the player presses the gas pedal. The auditory feedback helps the player to get an idea of how fast they are going, and whether they are accelerating or slowing down.

It should be noted that for the player to have awareness of their environment and movement, it is required of the player to have some basic knowledge of a car. The player's awareness is reliant on the player recognising key features of the car, like the steering wheel.

Finally, for the player to be aware of their performance, the player is given explicit messages and a numerical score to gauge how well they are doing. If the player does something well, they are awarded with points and a positive message. If the player loses control of the vehicle, they are told to drive carefully.

3.3.2 Iterative development

Iterative development is a development paradigm in which one continuously improves upon the previous work done. The paradigm is defined by dividing a project into smaller iterations, receiving feedback inbetween and changing course as needed during the project.

Following the human-centered design process, it was decided that an iterative development process would be chosen for the project. Iterative development is useful for large software projects, and especially for game and user experience projects as you are able to change your focus and direction based on feedback. This is called adaptive planning[5], and is a process which helps decide what features should be prioritised in accordance to user feedback. The goal of this process is to develop an artefact that is able to satisfy both the end users and experts.

The process included some development ideas from Scrum and agile methodology, such as userstory-like requirements and a kanban board for tracking implementation of features, though there were no daily stand-up meetings, mostly due to this being a one-person project.

3.3.3 Requirements

In order to keep track of the development and how well the prototype reflected the previously defined goals and desires, we wrote down requirements, similar to user stories. These requirements let us atomise the larger project into bite-sized chunks of development.

By the start of the project, we had identified basic requirements from interviews and problem definition, and as part of the adaptive planning process, we added new requirements and changed priorities as user testing highlighted what we needed to improve.

Requirements were marked by priority, in order to keep track of which requirement was most pressing to finish. Lesser important requirements, like those related to aesthetics instead of functionality were given lower priority.

When we decided to implement a tutorial into the game, we also broke it down into requirements to keep track of its development.

3.3.4 Kanban

A kanban board helps keep track of progress during development, and is common among software engineering projects. Requirements were written and placed on a kanban board, and a definition of done was defined to ensure that when a requirement was moved to done, its implementation was also done. We used the website Trello as our kanban board, as it lets us easily keep track of our requirements and lets us mark requirements with additional info, such as which iteration they belong to and their priority.

3.3.5 Testing

Our primary methods of testing have throughout the entire project been end-user testing and interviews. User testing is an integral part of human-centered design and ensures the quality of the software being developed. User testing is also useful in the context of iterative development, as user feedback can shape the direction of future iterations. Interviews with experts have given a good second opinion and gives a valuable impression from an insider.

Each iteration of development concluded with a round of intermediate testing, and feedback from the testers was taken into account when improving the

R1	The player must be able to control the car's speed and steering	Must
R2	The player must be able to use a virtual steering wheel to control the car, like a real car	Must
R3	The player will be given a score based on how they are driving	High
R4	The application should support any SteamVR compliant VR headset	Medium
R5	The application should be playable using only standard VR equipment	Must
R6	The player should be able to choose between different cars	Low
R7	Wildlife hazards should be placed on the road as obstacles	High
R8	The player should be rewarded for noticing and acknowledging the hazards	High
R9	The player should be able to reverse the car	High
R10	The player should be able to rewatch their driving for retrospective	Medium
R11	The game should showcase the difference between reflector use and non-use	Medium
R12	The camera should not give the player unreasonable motion sickness	High
R13	The player must be shown the controls of the game on their controllers	High
R14	The car should make sound to increase player awareness	Medium
R15	The radio should play music	Low
R16	The game should have a "for-fun" mode	Low
R17	The game should contain a linear experience	High
R18	The player should be able to place themselves safely back on the road in case of accidents	Medium
R19	The player should be given a summary of their performance at the end of a level	Medium
R20	Other cars should be placed on the road as obstacles, and the player should be rewarded for dimming their long lights properly	Medium
R21	The player should be able to toggle a view of the controls in case they forget	Low

Table 3.1: Requirements for the game

tR1	The player must be shown text explaining the controls of the game	High
tR2	The player must be given tasks where they try out all the primary controls of the game	High
tR3	The player should be given a linear progression and stage to pull them along	Medium
tR4	The player should be introduced to hazards in the tutorial	High
tR5	The player should be introduced to the score system in the tutorial	High
tR6	The tutorial should have a voice-over for accessibility and communication	Medium

Table 3.2: Tutorial requirements

prototype. Feedback was received through semi-structured interviews and observations. Observing your users while they are using your prototype can reveal a lot about a system's ease of use.

Several rounds of interviews were conducted with experts. One before development started, one in the middle of development, and a final round once development had concluded, where the experts could evaluate the prototype in its finished state. The final round of interviews had the most impact for the evaluation of the entire project.

In the case of interviews, we have made use of both rigid and free-form interviews. In cases where the questions were not really decided on beforehand, making use of an interview guide ensures important topics are asked about.

For the final user testing, we directed the interested testers to a website we had created to help them set up the application. We used a questionnaire as our data gathering method for these tests. As tests had to be done remotely, we unfortunately lost the ability to perform observations.

The data gathered has for the most part been qualitative, as the data we have been interested in is for the most part qualitative. Examples include whether they believe an application like this promotes self-paced learning or if they thought they could apply what they learned in a real-life scenario. Little quantitative data was of interest.

3.3.6 Game design

This section will describe game design decisions made. We will discuss the strategy used and outline how we will evaluate the game design.

The book Learning with digital games: A practical guide to engaging students in higher education[39] suggests a strong framework for designing serious games. By mapping learning objectives to game activities, you can get a good overview of how well your game design works as a learning tool. Not all learning objectives can be directly mapped to game activities, and can be done by out-of-game experiences or by using external tools.

Making a game where progress necessitates engagement with the learning mechanics increases the likelihood of your game being a successful learning tool. Using this framework helps ensure that we have a connection between the player's game experience and the player's learning outcome.

Learning Objectives	**Learning Activities**	**Game Activities**
Learning how to notice and be aware of potential hazards during night driving	Staying aware and noticing wildlife hazards while driving	The player will need to use their vision to notice wildlife objects in the game to increase their score and prevent collisions
Being able to keep a safe speed in night conditions	Reflecting on the effects of their speed, what happens if they gain score, collide or have other issues	The player will receive more points for keeping a safe speed, and will be deducted in points for unsafe driving. The player can also reflect upon their speed if they drive too fast into a corner and land in the ditch.
How to dim long lights when passing other cars	Practising the proper distance and speed at which to dim the lights	The player will be faced with oncoming cars, and will receive points for performing the dimming manoeuvre well, along with a message reinforcing their performance.

Table 3.3: Learning objectives

At the end of the project, we want to come back to this table and evaluate how well the game activities support the learning objectives.

Level Design

In order to make gameplay levels that are encouraging to the players, we want to ensure that there is a progressive difficulty curve. Making the gameplay progressively more challenging for the player keeps them invested in puzzle solving and intrinsic improvement. This ties back to the Flow principle.

Another important aspect is the idea of rest. We want to make sure that the player gets ample time to rest and recuperate after they have run into a challenging section. When creating the finalised levels for the game we ensured that hard, curvy mountainous roads are followed by a period of straight road where the player can rest and drop their pulse.

Chapter 4

Implementation

This chapter will go through each stage of development from beginning to end, and explain what elements were implemented at what time, and how they were implemented. Each iteration concludes by summarising what was learned and how the prototype could improve.

As is common with iterative development, changes that had to be done during development are documented in this chapter. This chapter aims to give an insight in what we spent most of our time doing, what problems we encountered and how we eventually solved them.

4.1 Pre-development

This section describes part of the problem definition period. While some choices, such as those relating to tools and process have already been documented, this section aims to give an insight into choices made that only affect the implementation.

4.1.1 Preliminary interview with NPRA

During the problem definition process we got in contact with the NPRA and invited them for an interview. During this interview we discussed what was unique about the Norwegian driving experience, and what people generally struggle with both during driving practice and after they've passed the test. When we mentioned our idea for a game, they brought up multiple points that they would like to see represented in a virtual environment.

Points of interest that came up were:

- Night driving and perception
- Ice driving
- Noticing and avoiding wildlife
- Keeping a safe speed, speed limits can seem too high in conditions with poor sight or ice

- Safety routines (check mirrors, seat belts, brake lengths)
- Learning new technology, in reference to how cars are getting more technologically advanced
- Reflector use

Out of these, the most interesting ones we agreed on were Night driving, ice driving, wildlife avoidance, safe speeds and reflector use. These all fit within the realm of safety and winter driving, and could be blended together to make something interesting which could hopefully have societal value. Some of these points would get higher priority over others.

We were particularly interested in the idea of the player's gaze, as VR gives a unique opportunity to track where players are looking. The NPRA representative mentioned how the driver's perception is an important part of safe driving, as taking your eyes off the road or not noticing something ahead of you is a common contributor to traffic accidents.

After the problem-definition phase we sat down and penned the first preliminary requirements for our application.

R1	The player must be able to control the car's speed and steering	Must
R2	The player must be able to use a virtual steering wheel to control the car, like a real car	Must
R3	The player will be given a score based on how they are driving	High
R4	The application should support any SteamVR compliant VR headset	Medium
R5	The application should be playable using only standard VR equipment	Must
R6	The player should be able to choose between different cars	Low
R7	Wildlife hazards should be placed on the road as obstacles	High
R8	The player should be rewarded for noticing and acknowledging the hazards	High
R9	The player should be able to reverse the car	High
R10	The player should be able to rewatch their driving for retrospective	Medium
R11	The game should showcase the difference between reflector use and non-use	Medium

Table 4.1: Requirements added for the first iteration

4.2 First iteration

Each of the following sections follow the same structure, and are aimed at explaining the features that were added in each iteration. This is to give insight into what state the prototype was in during each iteration and how development changed over the course of the project.

The first phase of the project consisted of mostly gathering information and planning for the future development of the project. This iteration followed development from a blank slate to the early signs of a runnable prototype. A prototype which could lay the groundwork for the most basic elements in the game, such as player interaction and a score system, the prototype we had at the end was essentially doing the legwork as a proof-of-concept for the future development.

4.2.1 Development summary

Development started with nothing more than a few basic geometric shapes and a horizontal plane to move around on. The chassis of the car is represented by a Unity Box Collider, with four Wheel Colliders attached. As we created something that could be defined as a "car", able to roll around and bump into things, more pieces were eventually added. The quintessential steering wheel was added, giving the player direct control of the car, as well as lights on the front of the car. Many of the parameters tied to the car are able to be tweaked, some from Unity's inbuilt systems and some values were implemented in such a way that they were easy to tweaked. Examples of this are which wheels are driving wheels, brake and torque values and the relation between rotating the steering wheel and the wheels' steering angle.

Towards the end of this development phase, a preliminary prototype featuring basic gameplay was finalised and prepared for testing. This prototype was exhibited at the XR.Tech conference in Stjørdal[1]. This prototype let users drive a car in a dark, open space. The prototype had a scoring system and a simple track enclosed by road cones which could be struck to deduct points. This let the testers attempt precision driving, putting both them and the application to the test.

A section of the track was dedicated to ice driving. Once the player entered this section, the car would gain new physics parameters. In order to emulate ice driving, the car has a completely different friction curve, causing the car to lose traction at a lot lower speeds.

This prototype was the basis of what the final game could become. As we had the most basic elements implemented, like the car driving, and some gamification elements. Testing the most basic elements of your prototype, regardless of graphical fidelity, is a common strategy to ensure your game is enjoyable at its core.[32].

[1]https://www.xrtechconference.com

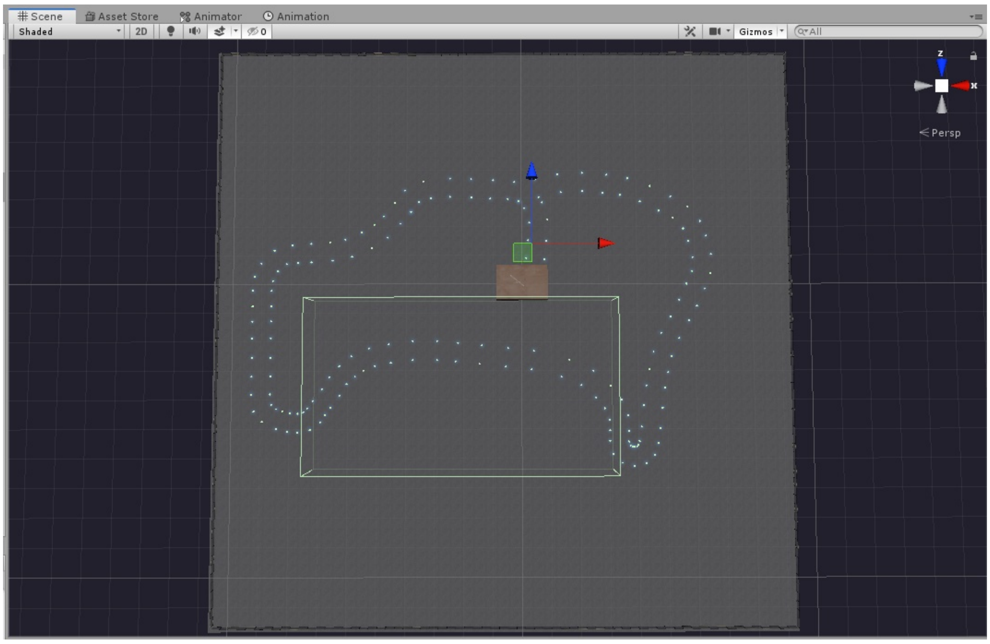


Figure 4.1: The track the first playtesters could play around on. The cones are highlighted to give players a track to follow. The green square is the section dedicated to ice driving.

Score

As part of the gamification process, a score system was integrated into the game. The player gains score by performing actions displaying safe driving, and the score can be used as indication of ones own performance, and can give a competitive element.

A score system is a good example of gamification because it gives players reinforcement. People like being rewarded, and positive reinforcement particularly is an effective way to communicate to your player that their actions are correct. By tying the score to the desired learning activities, we make it so that players chasing the highest score are the ones having the greatest learning outcome, and vice versa.[40]

In our game, we wanted to focus on positive reinforcement over negative reinforcement. In cases where negative reinforcement were implemented, we made sure it didn't act obstructive or too aggressively negative towards the player. The player should be directed in the right direction, not punished.

Cumulative speed score

As the player drives the car they gain a score based on how well they keep a consistent and safe speed. The score is calculated from how close they are to a specified target speed, and they will gain less points as they stray away from it, in the case that they're too far away from the target speed, they will gain no points. The target speed can be changed during gameplay to mimic speed limits, or by showing that the player should drive slower in a curvy mountain pass than on a straight road.

They also gain no score if they drive off the road. The game keeps track of the player's ground surface and only increments the score if they are safely on the tarmac. The player will also not gain any points if they perform unsafe manoeuvres, such as if they drive too fast, or lose traction, sending the car sideways.

An option to improve this mechanic is to make it only accumulate score while the player is on the right side of the road, to keep them in the correct lane. This was not implemented firstly due to complexity and time savings, as well as it not being too relevant of a point for our application.

```
//  Gives a constant rise in score based on how well you are keeping your speed - how close you are to the "optimal" speed, something which can be set by the game
speedScore = (5f - Mathf.Abs(tSpeed - rb.velocity.magnitude)) * Convert.ToInt32(!unsafeDriving) * OnRoad();
scoreManager.addToScore(Math.Max(speedScore, 0));
```

Figure 4.2: The speed score calculation, which is run once each in-game frame.

There is a point to be made that this does not easily translate into meaningful feedback, as the player has to keep track of how fast the score increases to actually translate that into feedback. In an attempt to counteract this, an animation was added to the number whenever it increments by a value of thousand. Adding this motion to the number can make it easier to track when you're scoring more points.

The primary point of the cumulative speed score is to set a standard for the player, and shows that if you do something wrong or poorly, you will not gain score, and may even have score deducted. The player must first gain points to lose points.

Bonus points

The player will receive extra points for performing certain tasks, such as noticing hazards and properly passing other cars.

These bonus points are represented by easily visible floating numbers (not to be confused with floating point numbers) intended to communicate to the player that they just earned some points, in some cases, a descriptive or celebratory text is accompanied. This form of positive reinforcement helps tell the player that they've done something desirable, so they can evaluate their actions and performance.

Score deduction

If the player were to do something bad, points could get deducted. This was implemented in the very first prototype, where hitting road cones would make the player lose 100 points, and a message would appear telling them to drive carefully.

Figure 4.3: The player receiving bonus points upon noticing a moose. The number rises up from the moose's position.

Figure 4.4: A player losing control of the vehicle and spinning out. This causes a warning message to appear.

SteamVR player

In the SteamVR library, one of the most important features is the inclusion of a prefabricated object which represents the player character. This object handles tracking of the three tracking points, headset and controllers. This includes position, rotation and button presses, allowing us to keep track of where the player is looking and moving their hands. This player object can be dragged and dropped into a virtual environment and will handle interactions from then on. In our case, we connected the player object to the car they are seated in, meaning that they will follow when the car drives.

SteamVR interactables

Additional to the SteamVR player, the SteamVR library contains helpful pre-packaged scripts which make certain interactions easier. These were used for a few core features. The circular drive interactable script, which lets the player grab an object and rotate it around a point, which is exactly what was needed for the steering wheel. A linear drive interactable script, made for objects which move along a linear axis, was used for dragging the gear shift lever back and forwards.

Controls

The basic controls were put in place, using SteamVR interactables the player was able to grab the steering wheel to make the car turn from side to side. In addition, the trigger buttons on the controllers were set to gas and brake pedals, right and left hand respectively.

Finally, one of the face buttons was set to toggle the long lights, which let the player get a taste of their effectiveness, and showing how night driving can be reflected in VR. Another face button was set to toggle the reverse gear.

The controls were somewhat rudimentary, and some parts were not very intuitive. We noticed some playtesters had very little previous experience with VR, and needed instructions on how to interact with their environment. To begin with, there were no indicators to tell the players what each button did, which wasn't a huge problem as we were observing them and could instruct in the case of confusion.

Another issue was that the steering wheel could only be grabbed by one hand at a time, this was a limitation of the SteamVR system. As we noticed playtesters wanted to grab with both hands, it became clear we needed to implement a better solution.

Ice driving

By changing parameters of Unity's Wheel Collider objects, we can manipulate the friction curves[2] of the wheels. This simulates the physics of a real-life wheel, describing how much grip the wheels have during turns and when they lose traction.

In order to simulate ice driving, we tweak these parameters to an extent where the player experiences a loss of traction at higher speed, similar to what you'd experience in the case of slippery roads.

4.2.2 Intermediate Testing

We had a testing setup at the Xr.Tech conference, where people could test the prototype one at a time. We received feedback from around 15 playtesters, and a handful of spectators shared a few points to us.

[2]https://docs.unity3d.com/ScriptReference/WheelFrictionCurve.html

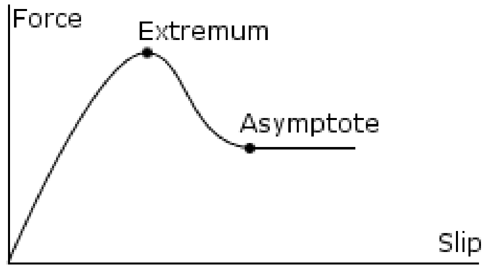


Figure 4.5: Example of a wheel friction curve, from Unity3d.com

The feedback was gathered through free-form interviews and discussions after people had played or observed the prototype, as well as through observing people while playing. Observing how people are interacting can be very helpful to get an understanding of how intuitive your user experience is. In some cases, if playtesters were having issues, we would help them.

Feedback at this conference was crucial for the future development of the prototype. It showed the potential, and gave a lot of pointers on how to proceed. A few egregious software bugs were unearthed, for example sometimes the player could drive into a cone and be sent flying. This could cause severe cybersickness. Questions and interview guides can be found in appendix C

4.2.3 Proceedings

People were pretty eager to try the prototype, and once they had the headset and controllers ready, people seemed to be having fun. Even though it was a basic and preliminary prototype, it was able to deliver an immersive and enjoyable experience.

There was a clear understanding that this was a basic prototype of a concept, and playtesters were positive to the concept. They believed VR equipment was a good idea for night driving learning.

Many of the playtesters were positive to the Knuckles controllers once they had them figured out. Many players were initially surprised at the lack of a tangible steering wheel, but in the end it did not hamper the experience.

It was clear that the application needed more direction, as players didn't always know what they were supposed to do. People also commented on how they didn't understand the score system, so it was clear that it needed more explanation. The application would also need to help ease people who are unfamiliar with VR into the experience. During observing, we often had to step in and help explain some of the controls and what they were doing. Some people are completely fresh to VR, and that has to be respected and worked around as a predisposition.

These new requirements were added or changed based on our evaluation:

R12	The camera should not give the player unreasonable motion sickness	High
R13	The player must be shown the controls of the game on their controllers	High
R14	The car should make sound to increase player awareness	Medium
R15	The radio should play music	Low
R16	The game should have a "for-fun" mode	Low
R17	The game should contain a linear experience, like a level	High

Table 4.2: Requirements added after the first iteration

4.3 Second iteration

The second phase was the phase where a lot of core functionality was fleshed out and developed. Based on the feedback gathered from the first iterations, new features were mapped out and prioritised. Then problems were tackled and a lot of features were implemented.

4.3.1 Development summary

Development of the hazard system was done entirely in this iteration. The hazard system consists of a view frustum and hazard objects for the player to notice. The mechanic was early decided to be one of the core mechanics of the game and we brought it out of ideation into the game in this iteration.

Some interactions were improved here, especially the steering wheel was made better, and some interactions were made more intuitive and immersive.

This iteration also saw the addition of sound. Sound is both an important part of game design and presence in VR spaces. While the most important sounds were added, more sound could still have been implemented.

Gaze and Hazards

The hazard system, as mentioned in the background chapter, is one of the core parts of the software, and a main part of the gameplay loop. The hazard system contains two core components, a hazard detecting frustum and the hazard prefab objects. These two components work together to create a novel gameplay element, modelling the importance of being aware of your surroundings and using your vision when you are driving.

Hazard detection

The hazard detection algorithm works by projecting a frustum from your head, using Unity's native mesh collider system.[3] The frustum is attached to the player

[3] https://docs.unity3d.com/Manual/class-MeshCollider.html

Figure 4.6: Comparison of your vision when toggling the long lights. During night driving in Norway, you're required to keep your long lights on, only turning them off if you meet other cars or there are street lights.

and follows their head movement as they look around. A ray is fired from the player's face, and as it collides with the environment, the frustum's length is set. In addition, the frustum has a max length, which changes depending on the long lights being active or not. It was unearthed during testing that the players had a tendency to look slightly downward, potentially due to the HMD weighing their head down, this caused some interesting issues with the hazard detection system, where a hazard would clearly be within the player's view, but not be registered as noticed, as the frustum's size would be limited due to hitting the ground. To mitigate this, the frustum is aimed at a slight angle upwards.

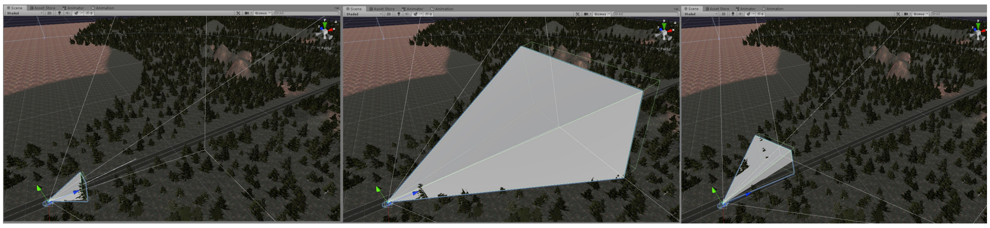


Figure 4.7: Comparison of the frustum's size. These images show the view frustum with long lights off, on, and when the ray fired collides with an object. Images taken from the Unity editor

Occluding walls

In order to prevent an issue where players could effectively peak over hills, we created an object that works as an occluding wall to block the player's view frustum. The vehicle cannot interact or collide with the wall and it is not visible, it only prevents the player's view frustum to pass through it.

The problem this presents is situations where the view frustum and the player's actual view do not correlate perfectly. In a worst-case scenario, this can lead to a player having "noticed" a hazard which never even entered their field of view.

This problem can still be present in places where the player scales a hill top, and can be solved by placing an occluding wall which is hidden when the player

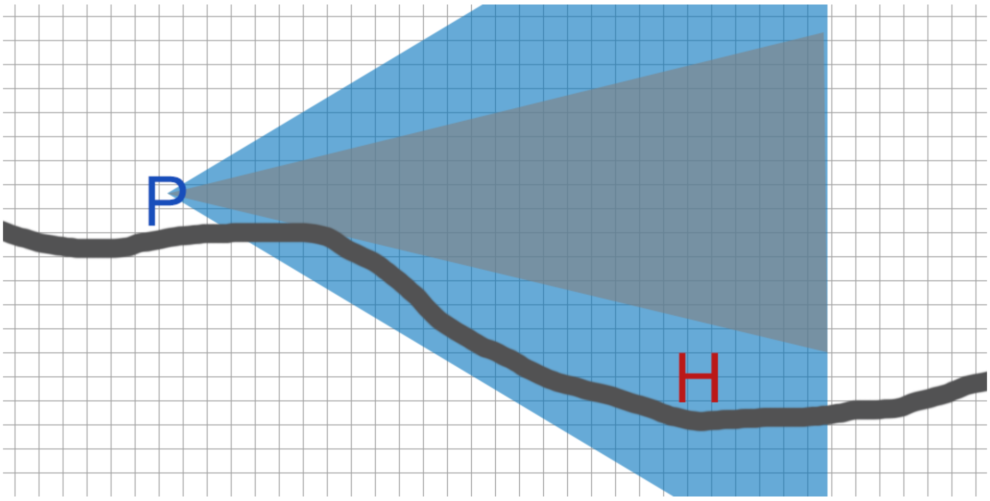


Figure 4.8: Graphic displaying a situation where the view frustum and player's view do not match. Grey is the player's actual view, blue is the projected view frustum. P and H are representing the Player and a Hazard respectively.

gets close enough, or change the gaze algorithm to account for hill tops.

Hazard objects

Hazard objects are one of the core parts of the game, they're essentially targets within our game, which our players want to use their perception to hit. The hazard objects contain several parameters that can be changed, and by using Unity's Prefab system, they can easily be placed and moved wherever you want them in the virtual environment.

The hazard objects were created by making a game object containing a Box Collider with a Layer Mask, causing it to only detect collisions with the above mentioned hazard detecting frustum, plus a script to handle their collision.

The hazard objects also have a 3D model of a deer or moose, along with a script to handle the behaviour of the hazard once it is noticed. In theory, one could place any 3D model to these other elements. Since we are using the Norwegian example of noticing deer animals, we are using models of deer animals.

A hazard object contains a public value for how many seconds it should be noticed for, and a value for how many points it should award the player when noticed.

The hazard object starts an internal timer as it enters the player's view frustum, and will count down while its in the player's sight. Once the timer reaches zero, the hazard object plays an animation, such as the animal walking away, and awards the player with bonus points.

A feature which was not fully implemented into the final prototype is the score deduction mechanic as mentioned in 4.2.1. If we had more time to develop, we would make the player lose points when involved in any kind of collision. A concern with the current prototype is that the player can collide with hazards without receiving any kind of penalty, and sometimes the player can receive a positive message following a collision. This can be seen in the following diagram, which shows this unfortunate occurrence compared to the desired outcome. This communicates the entirely wrong message to the player, as the score doesn't represent the goal.

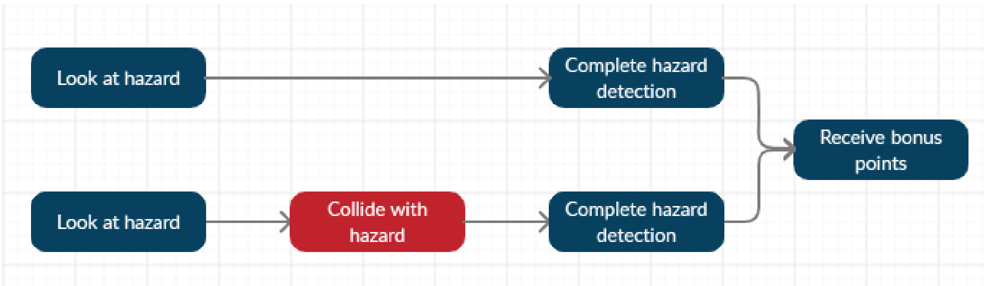


Figure 4.9: Diagram showing how the player can be gratified despite their poor performance.

Having contradictory score systems like this can be detracting from the learning experience, and it is contradictory to the set learning goals for the game. Therefore, this should've been changed before development finished.

Sound

Audio was added to the prototype during this iteration. Alongside ambient sounds came the sounds of the car: One for the idle engine and one for when the player is accelerating. Both of these sounds were taken from samples of cars running, and edited to make a seamless loop. As the player pushes the gas pedal, the accelerating sound increases both in volume and pitch, giving the player auditory feedback on their actions. The idle sound is also lowered as they accelerate.

More sounds can be added to the car to improve presence. Notably sounds for when the player is braking and when they collide. These were not added due to the complexity of implementing them in a way that wouldn't detract from the immersion.

There is no real usefulness in adding sounds to the wildlife. Primarily because you wouldn't hear anything from the inside of your car. It could also detract from the game's focus on vision.

Improved steering

Taking feedback from the first iteration to heart, the steering had to be improved. As of the first iteration, the steering wheel could only be grabbed by one hand at a time, and most people use both of their hands while driving. Due to the limitations of the SteamVR interaction system, a workaround solution had to be implemented. Instead of using a single Circular Drive interactable object, the steering wheel consists of three Circular Drive objects. One is only accessible by the left hand, and one is only accessible by the right. The third Circular Drive combines the output values of the two other objects' rotations and functions as the visual wheel.

Gear change

In order to make the reversing action more intuitive, we implemented a simple gear shift lever in the centre console. It emulates an automatic transmission, and only comes with "drive", "park" and "reverse" configurations.

The shift lever is composed of a SteamVR Linear Drive object, which lets the player move it backwards and forwards. The lever changes the car's state, its gear, depending on where the player moves it.

The idea of implementing a more complex manual shift lever and varying gears for the car was scrapped due to low priority, and that it doesn't help towards the learning objectives of our game. As we want the player to focus on night driving instead of how well they are managing their gears. It could be a better fitting addition in a larger-scaled game with a different focus.

4.3.2 Intermediate Testing

4 helpful testers from IMTEL gave intermediate feedback throughout this iteration, after certain features had been implemented and feedback was wanted for improvements. Since the IMTEL students are familiar with VR development, we could be more technical when asking questions.

The NPRA representative who we had interviewed before development started returned for an intermediate interview to see how development was going. They tested the prototype and were asked questions surrounding it. Additionally two representatives from NAV[4], a Norwegian department of labor and welfare, were visiting and tested the prototype.

The testers were observed during gameplay, and were asked some follow-up questions regarding what they found useful or not, plus what they would expect from the application in the final iteration.

Intermediate interview

As the NPRA representative visited we also sat down to have a structured interview to discuss the direction of the prototype.

They were positive to the current look of the prototype, and were quite impressed by the gaze mechanic. The idea of tracking the player's vision and attaching it to a game mechanic was a novel and interesting idea they liked.

Below are the points they brought up that we thought were interesting.

- Could place a scale model of Trondheim to practice city driving
- Would like some kind of story
- Crossroads

[4] https://www.nav.no/

- Retrospective
- Ability to test same scenario multiple times, maybe with different parameters
- Definitely need a tutorial to help people get started

4.3.3 Proceedings

It became clear that a tutorial should be made to make people understand the controls. When testing internally with students who were well versed with the prototype this wasn't brought up, but when external testers gave their feedback we realised the necessity of it. We also felt like the controls were intuitive enough, but were proven wrong.

Some of the playtesters had brought up that they didn't understand the scoring, so we decided to add a requirement to help explain.

We observed one playtester who mispressed buttons when wanting to go into reverse. After a discussion, he said he would like a feature reminding you what the buttons were.

R18	The player should be able to place themselves safely back on the road in case of accidents	Medium
R19	The player should be given a summary of their performance at the end of a level	Medium
R20	Other cars should be placed on the road as obstacles, and the player should be rewarded for dimming their long lights properly	Medium
R21	The player should be able to toggle a view of the controls in case they forget	Low
tR1	The player must be shown text explaining the controls of the game	High
tR2	The player must be given tasks where they try out all the primary controls of the game	High
tR3	The player should be given a linear progression and stage to pull them along	Medium
tR4	The player should be introduced to hazards in the tutorial	High
tR5	The player should be introduced to the score system in the tutorial	High
tR6	The tutorial should have a voice-over for accessibility	Medium

Table 4.3: Requirements added after iteration two, including tutorial requirements

4.4 Third iteration

This phase marked the finalisation of the prototype and was primarily marked by level design and implementing features which would assist players in understanding the gameplay. Since this was the final development phase, it was important that the end result was available to play out-of-the box and was comprehensible by testers. As the COVID-19 outbreak happened, and all testing had to be done remotely, the importance of this aspect increased.

No more development follows this iteration, and any evaluation done afterwards is the final, conclusive testing.

4.4.1 Development summary

This iteration contained a lot of important decisions and development. Previous iterations lacked cohesion and direction. In this iteration we built two levels for the player to play through, one being an optional tutorial level and the other being a finalised example level.

Following this, we will explain many key features of the finalised prototype, displaying how we solved the problems that arose.

The testing and evaluation of this iteration is in the following chapter, as it is the final evaluation of the prototype.

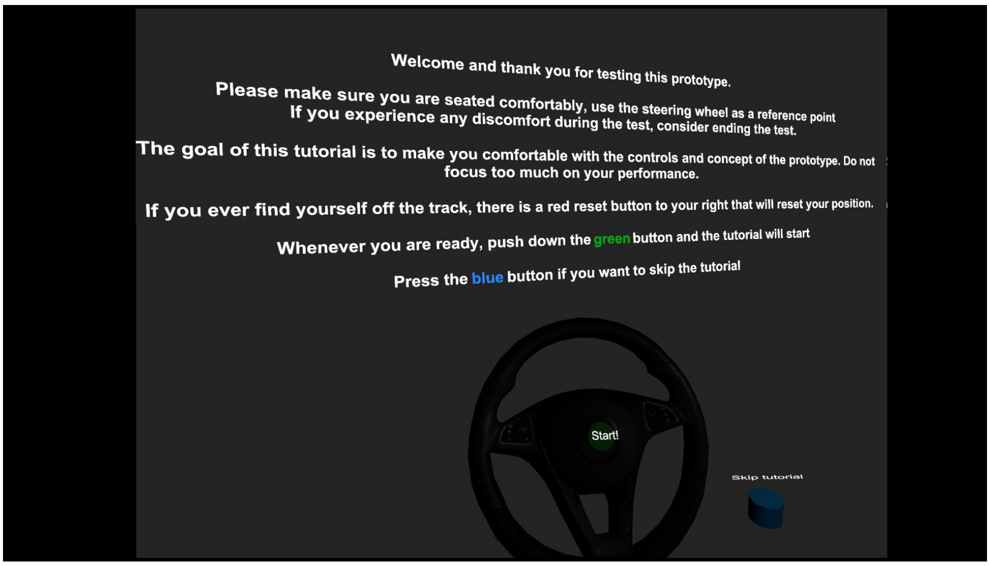


Figure 4.10: This is what greets the player once they start. By pressing the green button, they begin the tutorial, by pressing the blue button they can skip it.

Unity Terrains

Terrains[5] are a feature in Unity intended for design and development of large worlds and terrains as the name implies. A Unity Terrain is an easily manipulable plane, developers can use intuitive tools to change the terrain's height, material and even add terrain features such as trees. Using the softening brush was useful to make the terrain seem more natural, especially the hills.

Using this feature simplifies the process of creating an immersive world. This is not a game where boxing the player inside a house is acceptable, and we needed to create something with scale in order to ensure the environment is immersive.

Easyroads 3D

Easyroads 3D[6] is an asset downloadable from the Unity Asset Store that allows for simple creation of quality roads.

Easyroads 3D allowed us to drag and drop nodes, with road objects connecting between the nodes, akin to Bezier curves, and smooth out transitions in all three axes. This allowed us to make both realistic but also easily changeable roads, in case something was wrong, or didn't work well. In some cases we created turns that were unrealistically sharp, and could easily even that out after testing.

Perhaps the most useful part of the Easyroads 3D asset was its compatibility with Unity Terrains. The roads could bake the terrain and make the terrain conform to the roads instantly. This was good for development time.

The premium asset version of Easyroads 3D also includes extra features, such as intersections and side objects you can align with your roads, such as fire hydrants or reflective poles. In our prototype we did not make use of these premium features, but it can be of interest for future development.

The second hazard, passing car

To add a new challenge to the game, we added a second hazard in the form of a car driving in the opposite lane which the player would have to drive past. The idea is for the player to display their skill and knowledge of traffic rules by dimming the long lights and turning them back on again as they pass. They get a score and a bonus pop-up for that.

This is a common point of frustration for a lot of drivers, how passing drivers are dimming their lights too late, causing them to feel blinded, or too early, which can leave a large area ahead of both cars completely dark and dangerous hazards in the road can't be spotted.

We got some guideline numbers from NPRA regarding at what distance people are recommended to dim their long lights down when passing other vehicles. We modelled this into a variable score system where the player is rewarded for timing their light manoeuvres correctly. We added multiple levels to this to make the

[5]https://docs.unity3d.com/Manual/script-Terrain.html
[6]https://www.easyroads3d.com/v3/manualv3.html

player receive as much usable feedback as possible, instead of just telling them they are late, we can tell them if they are very late or slightly late. The levels are shown in Figure 4.12

The car stands still until the player enters a trigger to activate it. The car will then start driving along the road, in the correct lane. If the player doesn't dim their lights, they will gain no points. There is no advanced AI keeping the car on the road. It works on the same shell as the player character's car, and will only accelerate until a timer tells the object to self-destruct.

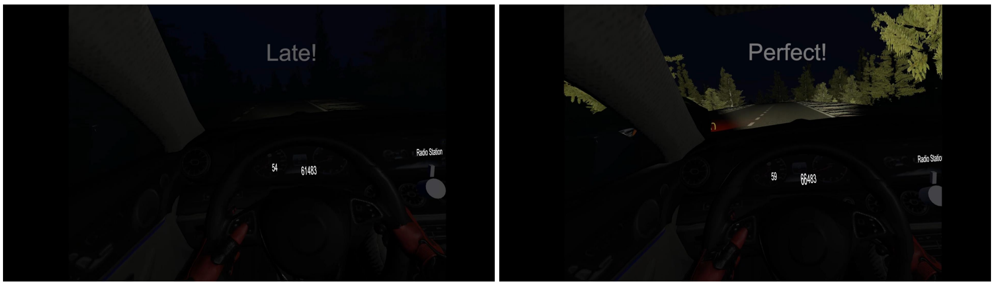


Figure 4.11: The player dimming their lights down and turning them back on as they pass a car.

Respawning

We noticed players often found themselves in the ditch. Sometimes reversing out of it was quite difficult, and it was obvious a mechanic to reset the player's position was needed.

This was implemented by placing invisible checkpoints with a pointer to a point in 3D space on the road. The player passes through these checkpoints, and the last checkpoint they passed will be saved as their respawning point. Once the player presses the large red button found in the centre console, the car will be placed on the saved checkpoint.

Extra interactions

To make the prototype more immersive and engaging, we changed some interactions, added long light toggle to a stalk the player has to actively interact with instead of relegating it to a simple button press. We also added a radio knob the player twists to play one of the four featured radio stations. This was a fun little addition that seemed to give people surprising amounts of enjoyment. Adding these extra interactions were useful for improving the immersion of the prototype, as well as making the actions more intuitive. In order to make these interactions more clear to the players, there are glowing "tips" to lead the player.

```
if (lights && !prevLights)
{
    float score = 0f;
    string text = "";
    if (!lightsAttempted && angleToPlayer < 90f)
    {
        if (distanceToPlayer > 50f)
        {
            score = 1000f;
            text = "Early!";

        }
        else if (distanceToPlayer > 25f)
        {
            score = 2500f;
            text = "Slightly early!";
        }
        else if (distanceToPlayer > 7f)
        {
            score = 5000f;
            text = "Perfect!";   // This is the sweet spot
        }
        else if (distanceToPlayer > 2f)
        {
            score = 1000f;
            text = "Slightly late!";
        }
        else
        {
            score = 1000f;
            text = "Late!";
        }

    }
    else if(!lightsAttempted && angleToPlayer >= 90f)
    {
        if(distanceToPlayer < 10f)
        {
            // a bit slow, get some points
            score = 500f;
            text = "Late!";
        }
        else
        {
            score = 0f;
            text = "Very late!";
        }
    }
```

```
if (lights && !prevLights)
{
    float score = 0f;
    string text = "";
    if (!lightsAttempted && angleToPlayer < 90f)
    {
        if (distanceToPlayer > 50f)
        {
            score = 1000f;
            text = "Early!";

        }
        else if (distanceToPlayer > 25f)
        {
            score = 2500f;
            text = "Slightly early!";
        }
        else if (distanceToPlayer > 7f)
        {
            score = 5000f;
            text = "Perfect!";   // This is the sweet spot
        }
        else if (distanceToPlayer > 2f)
        {
            score = 1000f;
            text = "Slightly late!";
        }
        else
        {
            score = 1000f;
            text = "Late!";
        }

    }
    else if(!lightsAttempted && angleToPlayer >= 90f)
    {
        if(distanceToPlayer < 10f)
        {
            // a bit slow, get some points
            score = 500f;
            text = "Late!";
        }
        else
        {
            score = 0f;
            text = "Very late!";
        }
    }
```

Figure 4.12: The score calculation for the passing car. Left is for when the player dims down, and right when they reactivate the lights. We use the distance between the cars to calculate. You can see at what stages the player gains the most points, and where they gain nothing.

Language

As the application was originally intended to be aimed at Norwegian learners, we had developed a lot of the text in the game in Norwegian. We realised that we needed to add English text in case we wanted international testers to help us evaluate. Due to this, there are two versions of the game, one in Norwegian and one in English. In a final product, we would like to see this as a setting instead of a separate executable.

Score summary

In order to fulfil requirement R19, we wanted to give the player a breakdown of how well they performed after finishing a level as shown in figure 4.16. When the player finishes, a text pop-up will be displayed summing up their score, and

Figure 4.13: Image of the interior, with a clearly marked bright red button for respawning.

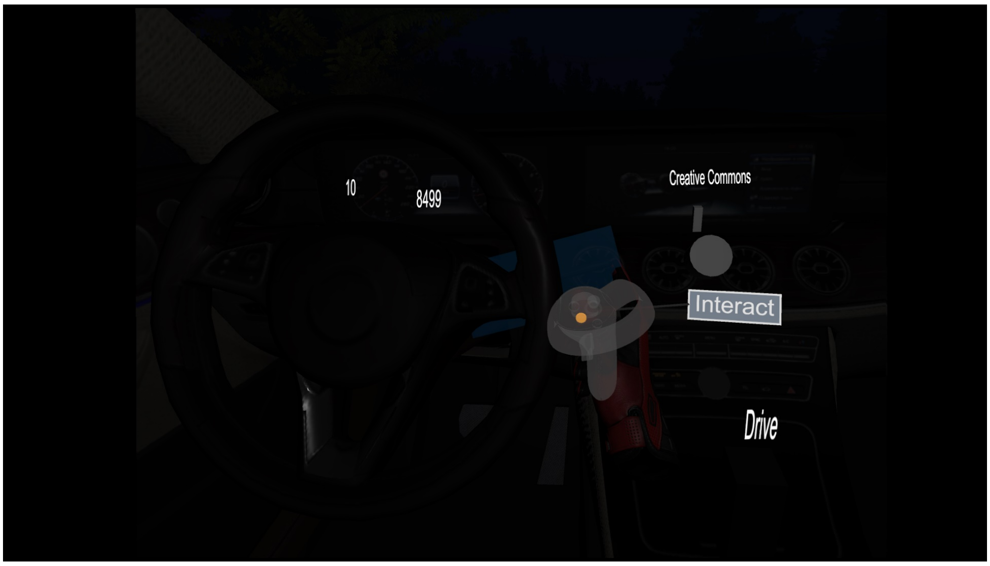


Figure 4.14: Image of the interior, after the player has been prompted to toggle the long lights. The long light stalk is glowing, and the player is shown what button to press.

giving them extra reinforcement of their performance. For example a player who managed to spot all hazards in a level, will be rewarded with a lot of points. We made it so players are rewarded for completing the level in a shorter time, which might seem contradictory to the idea of making players drive safely, but the score gained from driving safely outweighs the score gained from getting to the finish

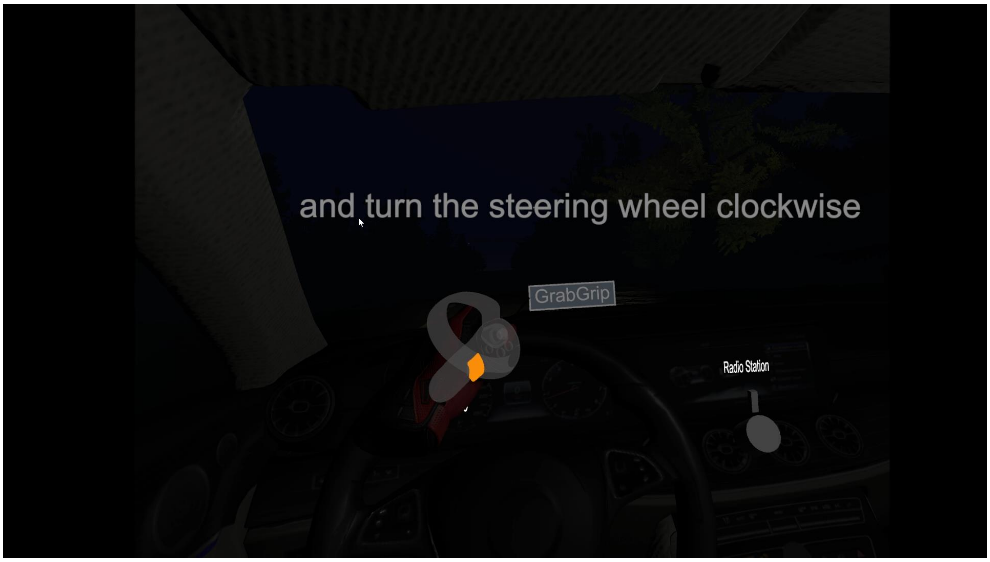


Figure 4.15: Image of the player grabbing with their left hand. Note the glowing button to indicate how to grab.

fast, meaning players can't game the system by driving recklessly. Instead it gives a nice number they can compare themselves to, and something which they can improve if they feel like it.

Figure 4.16: Summary of the player's score at the end of a level.

Tutorial

The tutorial stage was added to the game based on feedback and experiences from our early playtesters. Results showed that we needed some way to introduce the basic concepts of the prototype to the players, and to avoid needing surveillance by us and giving direct commands to players in person, a tutorial level was designed and built. We implemented it in a way that the player can choose to skip the tutorial if they are already familiar with the system.

In order to deliver the text instructions in the tutorial, we created a C# script containing helper methods for displaying the text, and methods that could take longer stretches of text to display to the player following a given interval.

The tutorial introduces each interactive element of the game, in a step-wise manner where the player has to display usage of one element before they can continue. The player starts out accelerating, braking and turning the steering wheel, before being taught more complex game mechanics, including an explanation of the score system. The player is told at multiple occasions to drive forwards and park at an illuminated and marked spot where they receive more instructions.

The tutorial is designed in a way that players can follow it easily, even if they have little to no prior experience in VR. One of the primary learning goals for the tutorial is to give the player confidence in how to use the system. Some VR applications can have a steep learning curve, which we want to avoid.

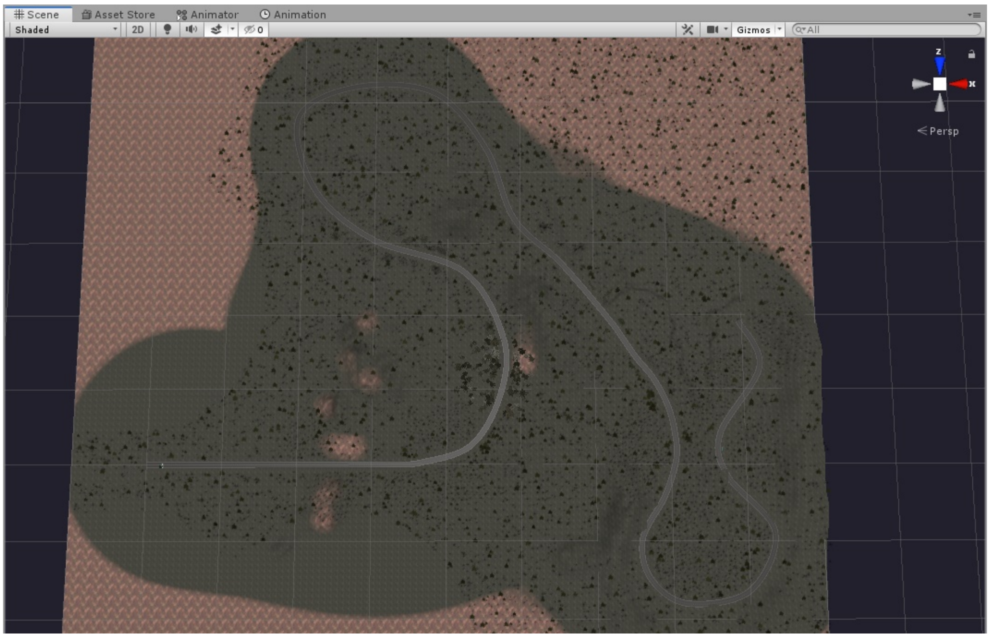


Figure 4.17: A top-down view of the tutorial map. The player starts in the bottom left corner and drives to the end of the road.

A full textual description of how to pass the tutorial is shown in Appendix D.

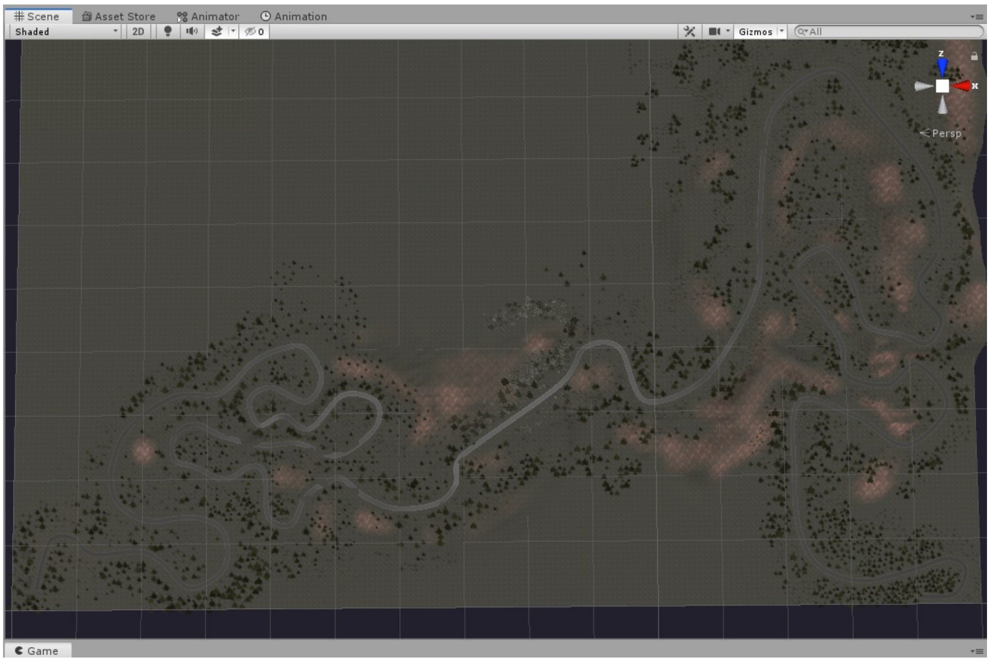


Figure 4.18: A top-down view of the final level. Again, the player is starting from the bottom left.

Level design

The largest addition to this iteration is an entire playable level, building on knowledge and mechanics developed during the project, we created a large stretch of road for the player to drive along, testing their abilities along the way.

The level is built using Unity Terrains and Easyroads3D. The level is designed to recreate the experience of driving on Norwegian country roads, so there are areas of heavy forest along with challenging roads consisting of curves and elevation changes. This is intended to display a variety of challenges that one might face when driving in Norway, giving the players essentially a cross-section of Norwegian driving all in one level.

Along the road, which measures 5.7km in length, there are placed 10 deer hazards and 2 passing car hazards. They are spread around erratically to keep the player guessing and ensuring that they stay aware.

We made use of the level design principles brought up in chapter 3, so in order to make the level more engaging we ensured that any difficult section was followed by a stretch where the player could drive more calmly.

Drift mode

This was a purely recreational alternative mode of play added where the player can practice an entirely different skill set than their safe driving. The drift mode is activated by dialling in to the Eurobeat FM radio station, which starts playing

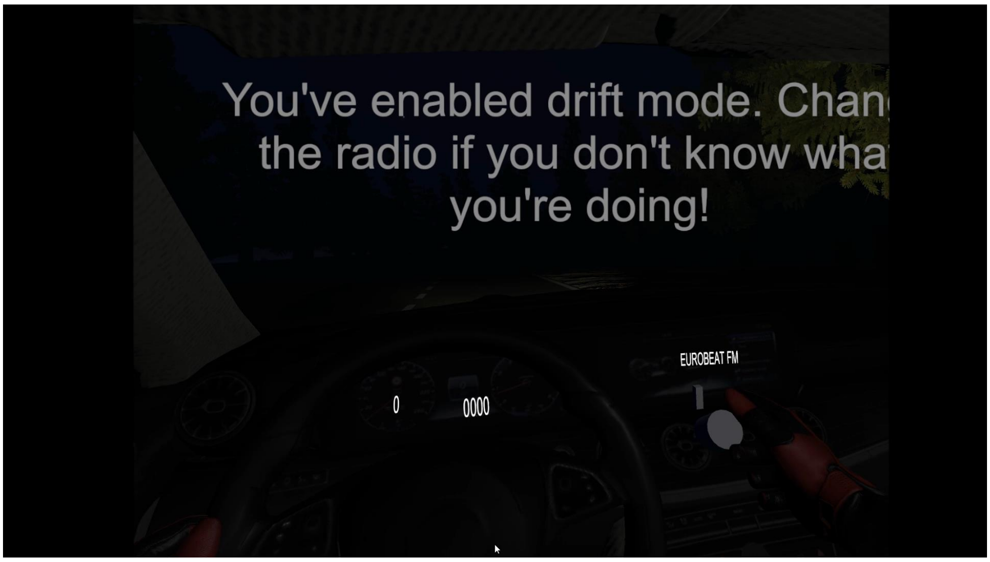


Figure 4.19: The player receiving a clear warning that they should leave drift mode if they are not aware of what they are doing. The whole text is more readable in the HMD view.

music of the Eurobeat genre, which is commonly associated with the car drifting scene in media. The player is given a clear warning on screen to change the radio station if they are not ready for it. We made use of the same idea as when we developed the ice driving 4.2.1, as we noticed some people were having fun during playtesting of the ice driving mechanic.

Once the player enters drift mode, the handling characteristics of the car are changed to make it easier to keep it sideways, in addition, the player no longer gains points by demonstrating safe driving, but by doing cool drifts, the score is calculated using the player's speed and turning angle. This has nothing to do with learning safe driving, and is instead a different recreational take, which also manages to showcase some of the flexibility of the system we have developed.

```
    float angle = Vector3.Angle(transform.TransformDirection(Vector3.forward), rb.velocity);

    // more points based on angle, 0 points if over 90 though
    // also based on speed, more speed equals more points
    if(angle > 90f)
    {
        angle = 0f;
    }

    speedScore = angle * rb.velocity.magnitude * OnRoad()/100f;
    scoreManager.addToScore(speedScore);
}
```

Figure 4.20: The piece of code handling the score calculation while in drift mode.

Chapter 5

Evaluation

This chapter details evaluation of the final prototype. The prototype was evaluated first by user testing and then by interviewing experts to get their perspective.

The primary focus has been on user testing, as that was found to be the most relevant method of testing for this application Discussion surrounding the evaluation will be in the next chapter.

5.1 User test results

User testing of the final prototype. The final prototype was a complete experience where the testers were able to play a tutorial to learn the ropes and test themselves in a full level.

Due to the Covid-19 pandemic, testing had to be done remotely. This caused issues because of no direct communication during testing. If the testers ran into technical problems, we would have to solve them over email instead of reaching out and assisting, making testing slower, less (difficulty of communication. couldnt help with technical problems. couldnt observe)

People were directed to the website https://vrdarkdriving.carrd.co which would give them the necessary information before they started. The site explains the basic knowledge needed before playing, as well as a link to the build, video walkthroughs and linking to the accompanying questionnaire.

The questionnaire we used to evaluate user testing consisted of 49 questions divided in 6 categories.

The first category, covers the tester's demographic and their testing conditions. This gives us an insight in how much experience they have with VR and night driving, as that can skew the results of their enjoyment.

The following categories concern questions of usability, gameplay evaluation, cybersickness and learning evaluation. All of these follow the Likert scale, where the testers give answers of how much they agree with a given statement.

The last category is aimed at receiving feedback for how to improve certain parts of the prototype, such as asking if they'd prefer a voice-over for the tutorial and if they enjoyed the drift mode if they tried it.

The questionnaire in its entirety can be found in Appendix A, with full results in Appendix B.

5.1.1 Results

For the final testing, we received sufficient answers from eight playtesters. Some of these were other students from IMTEL, some from high school students in Trondheim and some international helpers. The international helpers' answers may be seen as less relevant due to this application concerning itself with Norwegian conditions, though their input on usability and gameplay is valuable.

Figure 5.1, which displays the respondents answers surrounding the gameplay, shows that there are divisive opinions regarding the gameplay evaluation. There are a lot of individual factors and subjectivity involved, as someone may be less invested in the testing, and their lack of investment can make the levels feel too long, or the tutorial can be harder to follow.

We can see there is agreement in some questions, such as the tutorial is not seen as too difficult by any of the testers, and the controls were considered intuitive by all but one of the testers, who responded neutrally. All but one tester responded neutrally to whether they felt that their score reflected their performance, which is definitely interesting. Since none disagreed, it would be reasonable to assume they felt it represented some of their performance, but was maybe not a comprehensive evaluation of their performance as a whole. An assumption could be that they felt parts of the score system worked well, like the hazard detection, but not the accumulative speed score, or vice versa.

Interesting to note how most of the responses strongly agreed to adding more challenges and obstacles to the game, but two of the responses strongly disagreed. Could a middle ground that makes both sides satisfied be found?

Figure 5.2 shows a more positive trend, regarding the players evaluating the application's learning potential, but it's clear the testers are not completely in agreement. One respondent whose responses were weighted negatively in this category had experienced issues with the system at first, with regards to completing the tutorial. These issues affect player's view of the game, and obviously shouldn't occur. Being able to observe this player would have given a lot of useful feedback regarding what went wrong.

There is a consensus that this game, or one like it, can promote self-paced learning and most of the respondents believe it to be a good supplement to regular driving practice. Feedback shows that the testers believe they can apply what they learn in the game to real life, which may be an indicator of our learning goal framework working as intended. The testers unanimously didn't think this application, or one like it could completely replace driver training.

An interesting observation can be made when isolating the results of the players who had passed the Norwegian night driving course. One of the testers was the previously mentioned one who had experienced issues with the tutorial, so if we treat them as an outlier and isolate the remaining responses, we get the res-

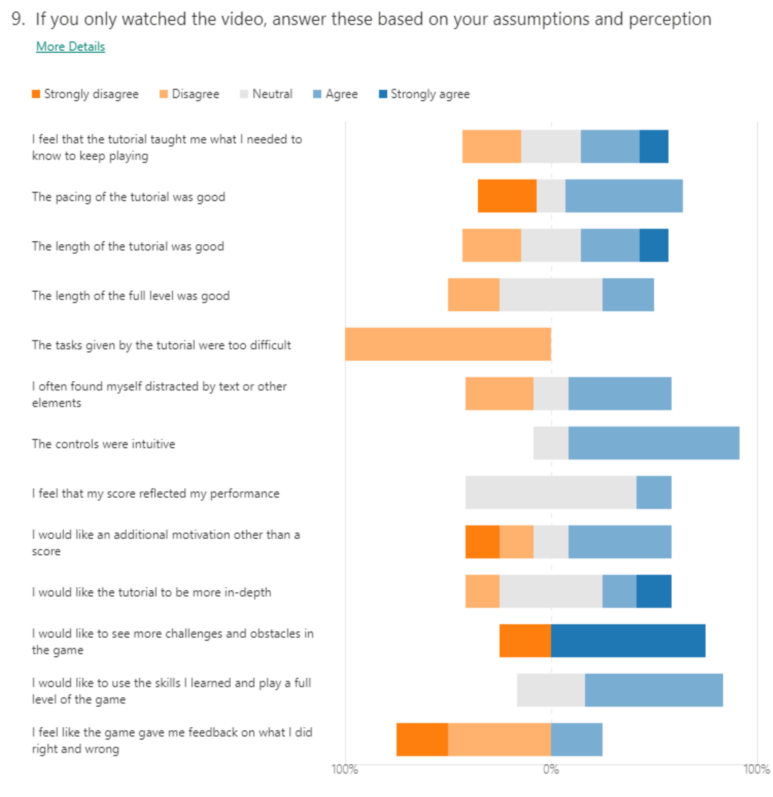


Figure 5.1: Gameplay results

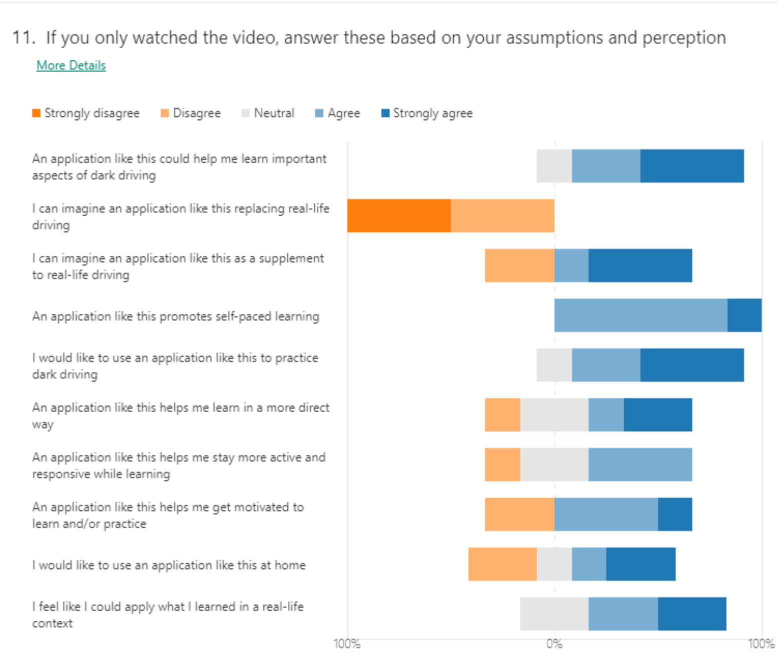


Figure 5.2: Learning results

ults shown in Figure 5.3. It's interesting to see the people more familiar with the subject matter being more positive to the learning experience, something which echoes the general sentiment from the driving instructors.

5.1.2 System Usability Scale

SUS, the System Usability Scale is a standardised scale used to gauge how usable a software system is.[1] The scale covers questions regarding how easy the system is to use, whether one would need help from an expert and if the system is consistent with well integrated features.

SUS is not to be used as a definitive judge, but gives a good estimate and overview of the software's usability.

The general trend as shown in figure 5.4 leans towards the system's usability being high, specifically regarding learning to use the system and its features. One tester said to have slight issues learning the system, which was discussed afterwards. It seemed to be more of an individual problem than systematic. There is complete agreement among the testers that they would not need the assistance of an expert to use the system, as well as that they believe most people would learn to use the system without problems, which is good for the case of remote learning and ease of use for our game.

Despite this, there's still a clear consensus among the respondents that it is

[1]https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

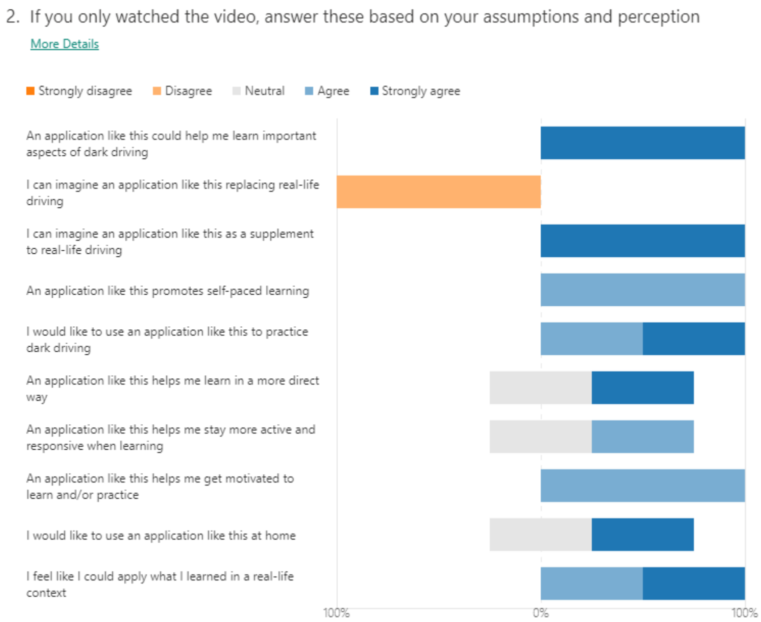


Figure 5.3: Familiarity with night driving

still a proof of concept and not a finished product. The rough edges can be seen as detractors to usability, but usability should come before form factor in applications like this.

Interesting to note the conflicting results surrounding whether the testers would want to use the system often. This could be chalked up to the individuals not having any need for driver training moreso than whether or not they enjoyed their time with the prototype. They could also not have any personal need for a game like this, so the point is not very relevant.

Multiple of the testers left a comment stating that they found the text during the tutorial portion difficult to read, that it was blocking their sight or disappeared too fast for them. Testers suggested many interesting ways of solving this, such as moving the text to a virtual screen, pausing motion until the player has acknowledged the text and to add a voice-over making it easier to digest the text.

5.1.3 Cybersickness

Half of the playtesters reported experiencing motion sickness of some kind, but not all of them to the point of nausea. Some of these could mostly be attributed to bad bugs. One player pointed specifically to an instance where the respawn mechanic had placed them in a spot where they'd continuously bounce rapidly. This made them very nauseous, and we ensured such a crucial bug was fixed asap.

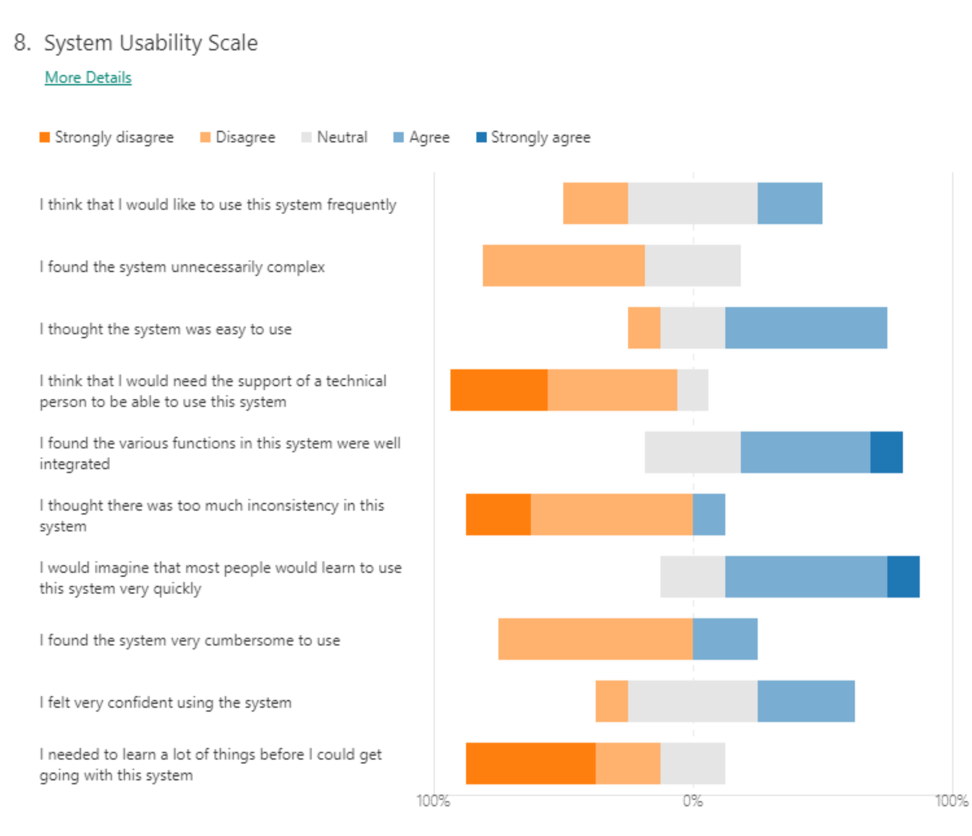


Figure 5.4: System Usability Scale results

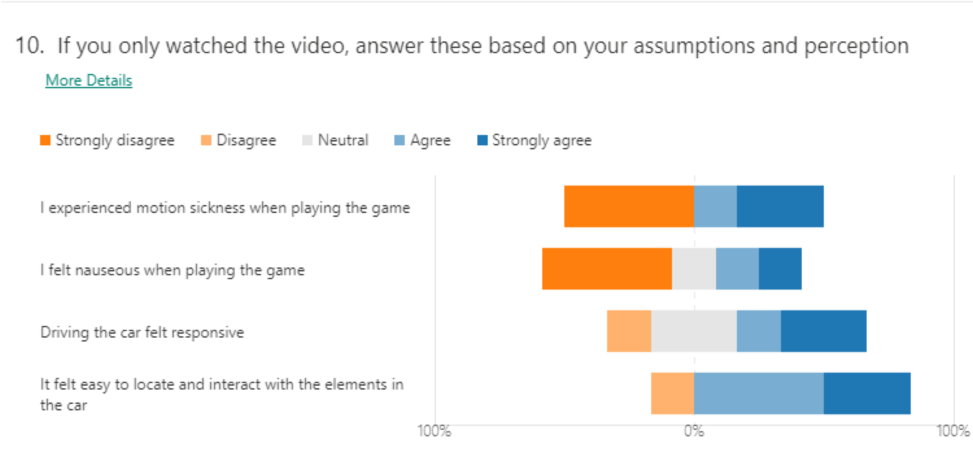


Figure 5.5: Cybersickness results

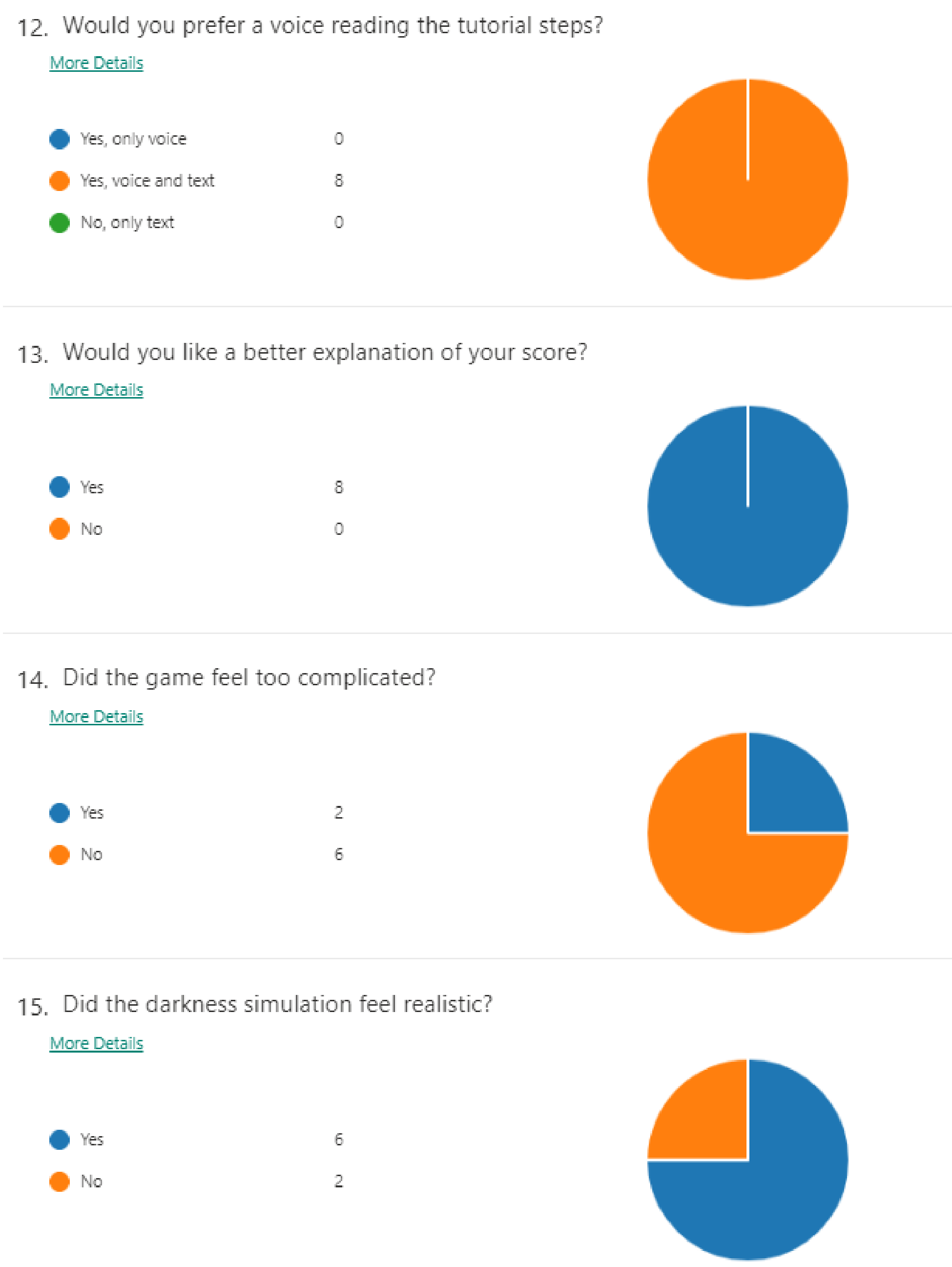


Figure 5.6: Extra improvements

5.1.4 Extra evaluation

The results shown in figure 5.6 show the responses to the final questions, which ask questions directly aimed at getting answers to improve the application in the future. With every single tester saying they would both want a voice over and text, as well as wanting a better explanation of their score, it is clear that we could've done some improvements in these regards. It is interesting to see two testers mention how they thought the game felt too complicated. As they didn't leave any comments, we can't clearly say why that is.

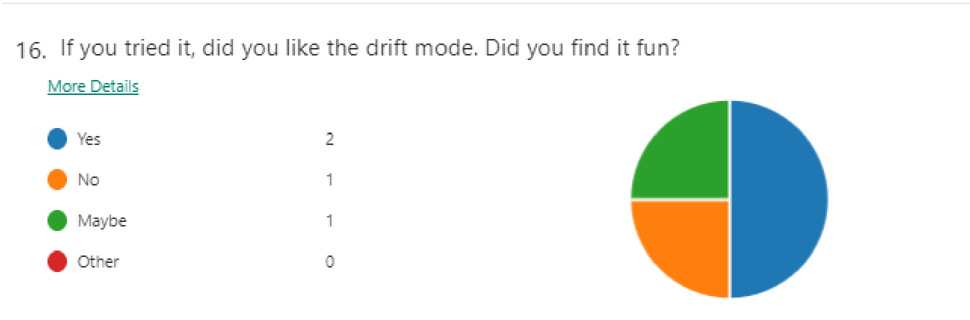


Figure 5.7: Drift results

Four of the eight testers tried the drift mode, and one of them said it was not fun. That's understandable, as the drift mode can be a bigger cause of cybersickness, due to its higher speed and more erratic movement.

5.2 Expert Interviews

In addition to questionnaires accompanying the user testing, feedback was gathered through interviews. Interviews conducted during development have already been covered in their respective chapters, and this section will only cover interviews giving direct feedback on the finalised prototype.

5.2.1 Driving schools

We interviewed four driving instructors from Wright traffic school in Trondheim[2], each of them with years of experience within the field. We performed two interview rounds, the first where three instructors were present at the same time, which lead to a lot of sharing of ideas and thoughts, and one interview with a single instructor. The instructors were shown the video walkthrough of the game prior to the interview.

The general consensus was that they were very positive to the idea and especially the focus on the gaze mechanic. They pointed out how the driver's gaze is one of the most important things, and can be quite difficult to learn.

When asked about whether they would want to use a system like this at their own traffic school, all the interviewees responded positively and would be interested in learning the system to be able to help out. They pointed out how they feel like the current night driving course is not adequate, with a lot of time wasted driving out to locations and little time spent learning.

When discussing challenges they find in the night driving course, one teacher brought up that keeping the learners' attention can be challenging. Their experience is that older people taking the course often come with more enthusiasm, as younger may feel like they are there out of obligation. It's difficult for them to know if the learners are actually taking the course to heart, as there is no test or examination afterwards to evaluate them. Another teacher pointed out how a lot of people take the course when they are young, and end up forgetting a lot of what the course offers by the time they get their learner's permit.

By the time we conducted the interviews, the Covid-19 pandemic had affected the field of driving instructing, and they had made use of remote learning platforms for teaching where in-person teaching is impossible. Whilst they had positive experiences with remote teaching, the tools used were limited and they would like better tools which improve learning and communication. They would be interested in using an application such as ours in case remote learning stays popular. The instructors were positive to having something that could make people learn by their own accord, through self-paced learning, and they think our application might have the ability to do that.

The instructors had brought up the point that a driver's perception is important for safety, and when we discussed the gaze and hazard mechanic implemented in the game, they were incredibly positive to the idea, and believed that combining

[2]https://wright.no/

such a mechanic with score systems seen in games can be a good way of improving enthusiasm among learning drivers.

They would really want to see more obstacles and scenarios, more specific things to be tested on. Some oddly specific ones, such as parked cars with high beams on. Listed below are the ones most interesting that were brought up, and could be brought into the prototype.

- Parked cars on the side of the road, with and without high beams on
- Parked cars with hazard lights on
- Passing cars in the same driving lane
- Scaling hilltops
- Pedestrian hazards
- City driving, poses different challenges with light
- Weather conditions, rain and snow block sight

A comprehensive list of the questions asked can be found in the interview guides in Appendix C, though it should be noted that some observations were brought up during casual, unscripted conversation.

Chapter 6

Discussion

This chapter will cover discussions around the testing and the overall completion of the project. We will interpret the test results, evaluate the process and compare our application to others.

6.1 Unfinished requirements

Here's a list of requirements that weren't finished, either due to time constraints or complexity.

R6	The player should be able to choose between different cars	Low
R10	The player should be able to rewatch their driving for retrospective	Medium
R11	The game should showcase the difference between reflector use and non-use	Medium
R21	The player should be able to toggle a view of the controls in case they forget	Low
tR6	The tutorial should have a voice-over for accessibility	Medium

Table 6.1: Unfinished requirements

Had this project gone on longer, we would focus on developing R10, as it seems like a new and interesting mechanic which can help with learning. It is however a rather complex requirement, and would require a lot of development time.

Another thing that we did not implement, even though it was not stated as an explicit requirement was making use of Unity's post-processing graphics stack[1]. Unity offers a good stack for optimising the look and feel of your game, and we would use this graphics stack had we had the time to learn it properly.

[1]https://docs.unity3d.com/Manual/PostProcessingOverview.html

6.2 Reflecting on process

Altogether, the process chosen has served well. Using Human-centered design ensured the quality of the application as we kept developing. The iterative development process was a deciding factor in effective and quality development. An improvement could've been to shorten the time frames of the iterations so we could have done more of them. This would've given stricter deadlines and smaller iterations, which could lead to features being tested more thoroughly. As it ended up, a lot of features were often tested at the same time at the end of their respective iteration.

The testing process by itself was good, but the implementation of the testing could've been improved. By the start of this project we had no idea we would be locked inside for months unable to meet up with people, and the effects of the Covid-19 pandemic had significant effects for how well we could test. Despite this, we do believe we could've done better with the hand we were dealt and pushed for more testers, particularly among other university students who might have access to VR equipment.

Another improvement to the process would be to test more alternatives of mechanics. Many game mechanics such as the cumulative speed score and danger detection could be more rigorously tested by having playtesters test different variations of them and evaluate their results.

Upon reflecting on the tools chosen, we are confident in our choices. Unity has served as a good game engine. While Unreal Engine or Cryengine could create higher graphical fidelity, Unity's user friendliness and accessibility outweighs the need for graphics. Unity's graphics did not hamper the efficacy of the application, neither in learning or immersion.

The Valve Index showed itself as an impressive HMD, and testers were often impressed by the interactions possible by the Knuckles controllers. The idea of using only low-cost VR equipment as opposed to dedicated steering peripherals is a novel and interesting idea, and has not shown clear downsides during this project. We do believe that using more advanced controllers, such as the Knuckles controllers, are better for this point, as they make the player emulate the motion of gripping in a more natural way.

6.3 Reflection on results

The results from the test subjects are hard to evaluate. There are a lot of divisive opinions and it is unkown to us whether individual factors are causing this or if there are greater issues with the system. There are some areas where we can clearly see a need for improvement, such as the tutorial lacking a voice-over and the score not being communicated clearly to the player. There are other areas where there is more agreement, such as the system's usability and intuitive controls, and responding that this is an application that promotes self-paced learning.

The positive feedback from experts is reassuring our belief that this is an application that can be used for learning night driving. Their openness to learning and using new technology is valuable for the game.

Bringing back table 3.3 from the chapter 3, we want to re-evaluate it to reflect on whether the game fulfils the learning objectives as intended.

Learning Objectives	**Learning Activities**	**Game Activities**
Learning how to notice and be aware of potential hazards during night driving	Staying aware and noticing wildlife hazards while driving	The player will need to use their vision to notice wildlife objects in the game to increase their score and prevent collisions
Being able to keep a safe speed in night conditions	Reflecting on the effects of their speed, what happens if they gain score, collide or have other issues	The player will receive more points for keeping a safe speed, and will be deducted in points for unsafe driving. The player can also reflect upon their speed if they drive too fast into a corner and land in the ditch.
How to dim long lights when passing other cars	Practising the proper distance and speed at which to dim the lights	The player will be faced with oncoming cars, and will receive points for performing the dimming manoeuvre well, along with a message reinforcing their performance.

The first learning objective is well implemented in the game. The game activity is tied to the gaze mechanic, which received very positive feedback from the experts. With experts bringing up how perception and awareness is important during night driving, making a mechanic that directly mimics this into the game and rewards the player directly is good. It could be explained better to the player.

The second learning objective is harder to evaluate entirely positively under the circumstances we have had. The game activity does not come through explicitly to players, and having an observer such as a driving instructor when playing could make this learning activity more effective. It's not entirely a failure, but it should be further developed to be able to work without external assistance.

The third learning objective is very well implemented in the game, with the players receiving immediate feedback on their performance and can evaluate how they can improve next time. This one might also be the one that requires the most pre-requisite knowledge of the players before they can make use of it, as it pertains to specific Norwegian traffic rules. We believe the mechanic could be explained better to the players to ensure the learning objectives are met.

6.3.1 Gaze tracking

From interviews with driving instructors and preliminary interviews with the NPRA, this game mechanic seems to be very useful. It is a novel idea, making good use of the capabilities VR equipment's ability to track the player's head movement. The gaze tracking mechanic showed good results among testers, though it might be a bit rough around the edges as of now. Some testers I spoke with did not completely understand it, but once it was explained to them in more detail, they thought it was a good addition. The player should become more aware of this mechanic during gameplay than what they currently are, so they can utilise it effectively and feel mastery.

With perception being one of the first important points brought up in our problem definition phase, we are very satisfied seeing this mechanic ending up as a core mechanic in the final prototype.

6.3.2 Usability

Based on the results of the System Usability Scale, the usability of the game is rather high. With outliers seemingly being attributed to individual factors more than the system itself. Results show that the system is easy to use and the interactions inside the game are intuitive and easy to understand. There are still improvements to be made to the system's usability, especially with how the game communicates to the player. The lack of a voice-over during the tutorial hampers the usability, and implementing requirement R21, allowing for players to toggle a view of the controls, would help players who find themselves confused or stuck inside the game. Similarly, some kind of pause menu would be helpful for players wanting to take a break, or needing to do something before resuming play.

We could have done more to prevent cybersickness. As discussed in the background chapter, blurring the player's field of view is an effective way of reducing cybersickness, but it was never implemented into our prototype. Another system that could be implemented would be to fade the player's vision to black if unnatural, potentially uncomfortable movement is discovered. This is already done in the game when moving from the tutorial to the final level, precisely to avoid cybersickness.

6.3.3 Score

The score system received inconclusive feedback, and we believe there is room for improvement.

Circling back to the idea of the score as a learning incentive, we want to use the lens of judgement from the Art of Game Design book to evaluate how good of a judge our score system is.[32] The lens of judgement has us ask the following five questions to evaluate whether the game is a good judge of the players.

What does your game judge about the players?

The game judges how well they maintain safe speeds and their skill at noticing hazards and performing manoeuvres such as dimming the long lights at the correct time intervals.

How does it communicate this judgment?

The game communicates this through a score number, for the hazards it is also communicated with an affirming or evaluating piece of text.

Do players feel the judgment is fair?

The test results show that people want a better explanation of their score. Arguably the current score system doesn't feel very fair to the players if they don't understand the complete context.

Do they care about the judgment?

We believe this point might be where the score system is lacking. Particularly the speed score might be hard for the player to understand and thus really care about. In the cases of the hazards, the player receive a message so they can tie the message to their performance easier. For the speed score this is more difficult to do.

Does the judgment make them want to improve?

If the players aren't aware of what the score really means, it's hard for them to know how to improve. With the passing car hazard, the player is given a very explicit text describing their performance, which is very good as it gives a pointer to how they can improve. More of these kinds of pointers can help with the player's reinforcement to make them want to improve.

6.4 Comparison

Compare the app and its results with the stuff brought up in state of the art This section will be concerned with comparing our prototype with other projects and products which were brought up in Chapter 2.4.

Comparing our project to the studies done at Nord Universitet[2], we are building on top of their results. They conclude that simulator usage has been shown to be a good learning supplement for night driving, and we propose a more explicit example of simulator, one containing specific features and also how it is used. By using a VR game that focuses on gaze tracking and perception, we showcase one kind of simulator that can be used. We also showcase the connection between learning and gamification, and how a gamified system can be used for learning in a night driving situation.

We're building on the To Drive Norwegian[1] thesis as it states that simulator use can be good for norwegian roads. They believe simulator usage might not be very relevant for practising in higher levels of traffic learning, but for lower levels such as theory and night driving it can have value. Our project shows that in the realm of night driving we can supplement regular driving practise. Our prototype, focusing on low cost and ease of use can help with domesticating driving simulators as they bring up, to show that simulators are no longer big and scary but can be regular things.

Finally, we want to compare our features to the commercial products showcased in Chapter 2

	Supported inputs	Learning	Local (Norwegian roads)	Night driving	Multiplayer	Gaze tracking
iRacing	Steering wheel, gamepad	X		X	X	
City Car Driving	Steering wheel, gamepad	X				
Way Simulator	Steering wheel	X	X	X		
Our game	VR Controllers	**X**	X	X		**X**

Table 6.2: Comparing our solution to the products showcased earlier.

Comparing our solution to others, our focus on the player's perception is novel and an idea that sets it apart from the others. Our solution is also the only one to support VR controllers as an input method, making it a less costly method of enjoying some virtual driving. This strengthens our belief that we have brought a novel idea to the field of VR-based driving simulators, by focusing on a unique set of features.

6.5 Limitations

Due to this being a solo project, time constraints and scope of the project is limited. With VR being an cross-disciplinary field, having a partner to cooperate with can be a big boost when developing something like this, as we can build around each other's strengths when developing. We would also maybe say that we chose a rather large scope, as we have developed a prototype from nothing, improved upon it over three iterations and also evaluating the prototype at the end. Due to the size of the scope, focus has had to be shifted towards certain areas, and in our case the development and the game itself has gotten more attention than the evaluation.

Considering how our primary output is the prototype and not the evaluation also definitely affect the results. A lot more time and effort was dedicated towards development of the prototype than on testing and researching, most notably affecting the final results.

As has already been mentioned multiple times, Covid-19 had huge impacts on the testing and development cycle. Without repeating ourselves too much, we can safely say Covid-19 limited test opportunities massively and caused a lower quality and quantity of testing for the final evaluation. The disruption of the development cycle also delayed the final iteration by a long time, and led to less time being used on testing, analysing results and report writing.

With the limited testing, the evaluations are also limited. Had we been able to perform more and better tests, we could have been able to draw more conclusive points towards the game's usability and value.

6.6 Research Questions

We will evaluate how well we have answered the research questions.

How can we teach young drivers in Norway safe night driving using VR technology?

By developing a serious game which captures the younger audience, we can help teach safe night driving. The literature examined in this report supports this claim, and our prototype is a step towards finding out exactly how we can solve the underlying problems.

How can we use gamification in order to learn safe driving?

We propose a unique solution in our prototype by using our gaze mechanic, where players are rewarded for displaying proficiency in danger awareness and showing regard for night driving. The driver's perception is considered a deciding factor for ensuring safe driving, and our application can be used to teach learning drivers how to properly stay alert.

Can a VR application help with remote learning of safe driving

Our testing conditions show that our application can be tested and used remotely. The interviews conducted with experts agree with our belief. There might be a need for more remote learning in the future and we believe our application, or one like it, can be a solid aid. Additionally, by making our application only make use of low-cost VR equipment, accessibility and shareability of the application is higher. The application doesn't have to be set up at a driving school or university, but can insteat be used at high schools or at home.

6.7 Contribution

Our contribution is a prototype of a virtual reality serious game, aimed at helping young drivers learn and practice night driving in Norwegian conditions. The prototype introduces a novel mechanic making use of VR technology, by focusing on the player's perception and their ability to be aware of and react to dangerous situations when driving. By creating game mechanics and reward systems that tie to desired behaviour when night driving, we believe the game has potential to be a good learning experience. By making use of low-cost VR equipment, we ensure that our prototype can easily be used by more people, without sacrificing necessary fidelity.

The prototype builds on previous work related to night driving and simulator usage, and we hope our contribution can serve as a helpful contribution to an evolving field.

6.8 Further work

Since some requirements were left unimplemented, we would like to see them, at least the ones with higher priority, implemented.

While results have been mostly positive, more testing is needed to get conclusive results of the system's value. We have shown that a VR serious game can be a good tool for night driving learning and practice, but it remains to be concluded whether our prototype can be the one to fill in that slot.

From the early interviews with the NPRA to the final evaluation by driving instructors, the idea of giving players the ability to replay certain scenarios in order to practice these scenarios a lot was an interesting idea. A future revision of the game could have players choose between smaller levels focused on learning single things, as opposed to the current design where players drive through a longer level to train their whole skillset. We believe this might be a better way of having players learn, as they can focus on specifically the challenges they want to overcome and practice. When doing so, we would also like to add a lot more interesting scenarios and parameters for the player to experience, such as the ones brought up by the driving instructors.

Chapter 7

Conclusion

We have successfully developed a prototype of a virtual reality serious game to be used for helping young Norwegian drivers learn safe night driving. The game runs on low-cost VR equipment, which increases accessibility without sacrificing interactivity or immersion. The game offers a unique way of learning night driving, with a focus on the learner's perception. By using game elements we have created an engaging experience which aims to increase learning and enthusiasm for night driving, leading to safer traffic and fewer accidents. The focus on perception ties well in with night driving, and are combined together with gamification to help increase learning. Game elements have been designed and a working prototype built on the Unity game engine has been written to deliver this experience

We have not found any conclusive evidence that our prototype helps with learning, but more evaluations can be done to find out what currently works well and to receive more data that can support our belief that this game is a good supplement for helping young drivers learn driving. We also present what further work can be done to the prototype to see it improve.

Bibliography

[1] T. O. Holmquist, 'Å kjøre norsk', Master's thesis, NTNU, 2019.

[2] G. B. Sætren, C. Lindheim, M. R. Skogstad, P. Andreas Pedersen, R. Robertsen, S. Lødemel and P. J. Haukeberg, 'Simulator versus traditional training: A comparative study of night driving training', in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, SAGE Publications Sage CA: Los Angeles, CA, vol. 63, 2019, pp. 1669–1673.

[3] G. B. Sætren, P. A. Pedersen, R. Robertsen, P. J. Haukeberg, M. Rasmussen and C. Lindheim, 'Simulator training in driver education–potential gains and challenges', 2018.

[4] B. J. Oates, *Researching information systems and computing*. Sage, 2005.

[5] C. Larman, *Agile and iterative development: a manager's guide*. Addison-Wesley Professional, 2004.

[6] S. Barab, M. Thomas, T. Dodge, R. Carteaux and H. Tuzun, 'Making learning fun: Quest atlantis, a game without guns', *Educational technology research and development*, vol. 53, no. 1, pp. 86–107, 2005.

[7] (). How virtual reality can create the ultimate empathy machine, [Online]. Available: `https://www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_empathy_machine` (visited on 05/06/2020).

[8] (). Franklin institute | what's the difference between ar, vr and mr?, [Online]. Available: `https://www.fi.edu/difference-between-ar-vr-and-mr` (visited on 08/07/2020).

[9] (). Voices of vr | 50 years of vr with tom furness, [Online]. Available: `http://voicesofvr.com/245-50-years-of-vr-with-tom-furness-the-super-cockpit-virtual-retinal-display-hit-lab-virtual-world-society/` (visited on 17/07/2020).

[10] M. Cha, S. Han, J. Lee and B. Choi, 'A virtual reality based fire training simulator integrated with fire dynamics data', *Fire Safety Journal*, vol. 50, pp. 12–24, 2012.

[11] (). Walmart | how vr is transforming the way we train associates, [Online]. Available: `https://corporate.walmart.com/newsroom/innovation/20180920/how-vr-is-transforming-the-way-we-train-associates` (visited on 17/07/2020).

[12] J. Cremer, J. Kearney and Y. Papelis, 'Driving simulation: Challenges for vr technology', *IEEE Computer Graphics and Applications*, vol. 16, no. 5, pp. 16–20, 1996.

[13] B. R. Kim, M. H. Chun, L. S. Kim and J. Y. Park, 'Effect of virtual reality on cognition in stroke patients', *Annals of rehabilitation medicine*, vol. 35, no. 4, p. 450, 2011.

[14] M. Slater and S. Wilbur, 'A framework for immersive virtual environments (five): Speculations on the role of presence in virtual environments', *Presence: Teleoperators & Virtual Environments*, vol. 6, no. 6, pp. 603–616, 1997.

[15] E. D. Ragan, A. Sowndararajan, R. Kopper and D. A. Bowman, 'The effects of higher levels of immersion on procedure memorization performance and implications for educational virtual environments', *Presence: Teleoperators and Virtual Environments*, vol. 19, no. 6, pp. 527–543, 2010.

[16] J. J. LaViola Jr, 'A discussion of cybersickness in virtual environments', *ACM Sigchi Bulletin*, vol. 32, no. 1, pp. 47–56, 2000.

[17] C. M. Oman, 'Motion sickness: A synthesis and evaluation of the sensory conflict theory', *Canadian journal of physiology and pharmacology*, vol. 68, no. 2, pp. 294–303, 1990.

[18] M. Treisman, 'Motion sickness: An evolutionary hypothesis', *Science*, vol. 197, no. 4302, pp. 493–495, 1977.

[19] G. E. Riccio and T. A. Stoffregen, 'An ecological theory of motion sickness and postural instability', *Ecological psychology*, vol. 3, no. 3, pp. 195–240, 1991.

[20] F. Weidner, A. Hoesch, S. Poeschl and W. Broll, 'Comparing vr and non-vr driving simulations: An experimental user study', in *2017 IEEE Virtual Reality (VR)*, 2017, pp. 281–282.

[21] J. T. Reason, 'Motion sickness adaptation: A neural mismatch model', *Journal of the Royal Society of Medicine*, vol. 71, no. 11, pp. 819–829, 1978.

[22] A. Rolnick and R. Lubow, 'Why is the driver rarely motion sick? the role of controllability in motion sickness', *Ergonomics*, vol. 34, no. 7, pp. 867–879, 1991.

[23] R. Venkatakrishnan, R. Venkatakrishnan, A. Bhargava, K. Lucaites, H. Solini, M. Volonte, A. Robb, S. V. Babu, W.-C. Lin and Y.-X. Lin, 'Comparative evaluation of the effects of motion control on cybersickness in immersive virtual environments', in *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, IEEE, 2020, pp. 672–681.

[24] J. Jerald, 'The vr book: Human-centered design for virtual reality', Oct. 2015. DOI: `10.1145/2792790`.

[25] P. Budhiraja, M. R. Miller, A. K. Modi and D. Forsyth, 'Rotation blurring: Use of artificial blurring to reduce cybersickness in virtual reality first person shooters', *arXiv preprint arXiv:1710.02599*, 2017.

[26] I. Haldorsen and I. Munch-Olsen, 'Høyrisikogrupper i vegtrafikken: Samlerapport', 2011.

[27] *Vilt og trafikk prosjektrapport 2010-2017*, Vilt og Trafikk. [Online]. Available: `https://www.viltogtrafikk.no/wp-content/uploads/sites/24/2019/01/Vilt-og-trafikk-Prosjektrapport-2010-2017-endelig-jan.-19.pdf`.

[28] S. Deterding, S. Björk, L. Nacke, D. Dixon and E. Lawley, 'Designing gamification: Creating gameful and playful experiences', *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pp. 3263–3266, Jan. 2013.

[29] S. McLeod, 'Skinner-operant conditioning', *Retrieved from*, 2015.

[30] E. L. Deci and R. M. Ryan, *Handbook of self-determination research*. University Rochester Press, 2004.

[31] S. Nicholson, 'A recipe for meaningful gamification', in *Gamification in education and business*, Springer, 2015, pp. 1–20.

[32] J. Schell, *The Art of Game Design: A book of lenses*. CRC press, 2008.

[33] G. Zichermann and C. Cunningham, *Gamification by design: Implementing game mechanics in web and mobile apps*. " O'Reilly Media, Inc.", 2011.

[34] S. Alves, A. Marques, C. Queirós and V. Orvalho, 'Lifeisgame prototype: A serious game about emotions for children with autism spectrum disorders.', *PsychNology Journal*, vol. 11, no. 3, 2013.

[35] D. Checa and A. Bustillo, 'A review of immersive virtual reality serious games to enhance learning and training', *Multimedia Tools and Applications*, vol. 79, no. 9, pp. 5501–5527, 2020.

[36] P. Gamito, J. Oliveira, C. Coelho, D. Morais, P. Lopes, J. Pacheco, R. Brito, F. Soares, N. Santos and A. F. Barata, 'Cognitive training on stroke patients via virtual reality-based serious games', *Disability and rehabilitation*, vol. 39, no. 4, pp. 385–388, 2017.

[37] A. Ali, A. Elnaggarz, D. Reichardtz and S. Abdennadher, 'Gamified virtual reality driving simulator for asserting driving behaviors', in *2016 1st International Conference on Game, Game Art, and Gamification (ICGGAG)*, IEEE, 2016, pp. 1–6.

[38] J. D. Gould and C. Lewis, 'Designing for usability: Key principles and what designers think', *Communications of the ACM*, vol. 28, no. 3, pp. 300–311, 1985.

[39] N. Whitton, *Learning with digital games: A practical guide to engaging students in higher education*. Routledge, 2009.

[40] S. Scheider, M. Raubal, P. Kiefer, C. Sailer and P. Weiser, 'Score design for meaningful gamification', 2015.

Appendix A

Questionnaire

Dark Driving Practice simulator

A questionnaire accompanying the Virtual Reality (VR) learning game developed at IMTEL, NTNU, aimed at teaching safe driving in darkness
If you have any direct questions, don't be afraid to email me at stian.sorli@ntnu.no

Section 1 ...

By answering you agree to the gathering of anonymized, non-personal data more information

More information can be found at: https://drive.google.com/open?id=18w53JTWRpjbrMdguPfLIf_ro_Mx00uCw

Section 2 ...

First, some basic questions

1. What is your age group? *

- 0-20
- 21-30
- 31-40
- 41-50
- 51+

2. Which of these describe yourself? *

- Student
- Employed
- Expert in the field (i.e. driving instructor)
- Other

3. How true are these statements? *

	Very untrue	Untrue	Neutral	True	Very true
I have a lot of experience with VR	◯	◯	◯	◯	◯
I have a lot of experience driving cars	◯	◯	◯	◯	◯
I enjoy playing video games	◯	◯	◯	◯	◯

4. Have you passed a dark driving course? (Trafikant i mørket/Mørkekjøring) *

◯ Yes

◯ No

Section 3 ...

5. Did you play the game with a VR headset or watch the video playthrough? *

◯ VR headset

◯ Video

Section 4 ...

Answer these questions as accurate as you can

6. What language did you play the game in? *

- Norwegian
- English

7. What VR headset (and controllers) did you use? *

- Oculus Rift
- Oculus Quest
- HTC Vive
- Valve Index
- HP Windows MR Headset
- Other

8. System Usability Scale *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think that I would like to use this system frequently					
I found the system unnecessarily complex					
I thought the system was easy to use					
I think that I would need the support of a technical person to be able to use this system					
I found the various functions in this system were well integrated					
I thought there was too much inconsistency in this system					
I would imagine that most people would learn to use this system very quickly					
I found the system very cumbersome to use					
I felt very confident using the system					
I needed to learn a lot of things before I could get going with this system					

Game Design principles - answer as accurately as you can

9. If you only watched the video, answer these based on your assumptions and perception

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I feel that the tutorial taught me what I needed to know to keep playing	○	○	○	○	○
The pacing of the tutorial was good	○	○	○	○	○
The length of the tutorial was good	○	○	○	○	○
The length of the full level was good	○	○	○	○	○
The tasks given by the tutorial were too difficult	○	○	○	○	○
I often found myself distracted by text or other elements	○	○	○	○	○
The controls were intuitive	○	○	○	○	○
I feel that my score reflected my performance	○	○	○	○	○
I would like an additional motivation other than a score	○	○	○	○	○
I would like the tutorial to be more in-depth	○	○	○	○	○
I would like to see more challenges and obstacles in the game	○	○	○	○	○
I would like to use the skills I learned and play a full level of the game	○	○	○	○	○
I feel like the game gave me feedback on what I did right and wrong	○	○	○	○	○

Comfort and confidence - answer as accurately as you can

10. If you only watched the video, answer these based on your assumptions and perception

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I experienced motion sickness when playing the game	○	○	○	○	○
I felt nauseous when playing the game	○	○	○	○	○
Driving the car felt responsive	○	○	○	○	○
It felt easy to locate and interact with the elements in the car	○	○	○	○	○

Section 7 ...

Driving and learning - answer as accurately as you can

11. If you only watched the video, answer these based on your assumptions and perception

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
An application like this could help me learn important aspects of dark driving	○	○	○	○	○
I can imagine an application like this replacing real-life driving	○	○	○	○	○
I can imagine an application like this as a supplement to real-life driving	○	○	○	○	○
An application like this promotes self-paced learning	○	○	○	○	○
I would like to use an application like this to practice dark driving	○	○	○	○	○
An application like this helps me learn in a more direct way	○	○	○	○	○
An application like this helps me stay more active and responsive while learning	○	○	○	○	○
An application like this helps me get motivated to learn and/or practice	○	○	○	○	○
I would like to use an application like this at home	○	○	○	○	○
I feel like I could apply what I learned in a real-life context	○	○	○	○	○

Section 8 ...

Nitpicks and extras

None of these questions are required, if you want to finish, press submit. These questions are to help improve quality of the application.

12. Would you prefer a voice reading the tutorial steps?

- Yes, only voice
- Yes, voice and text
- No, only text

13. Would you like a better explanation of your score?

- Yes
- No

14. Did the game feel too complicated?

- Yes
- No

15. Did the darkness simulation feel realistic?

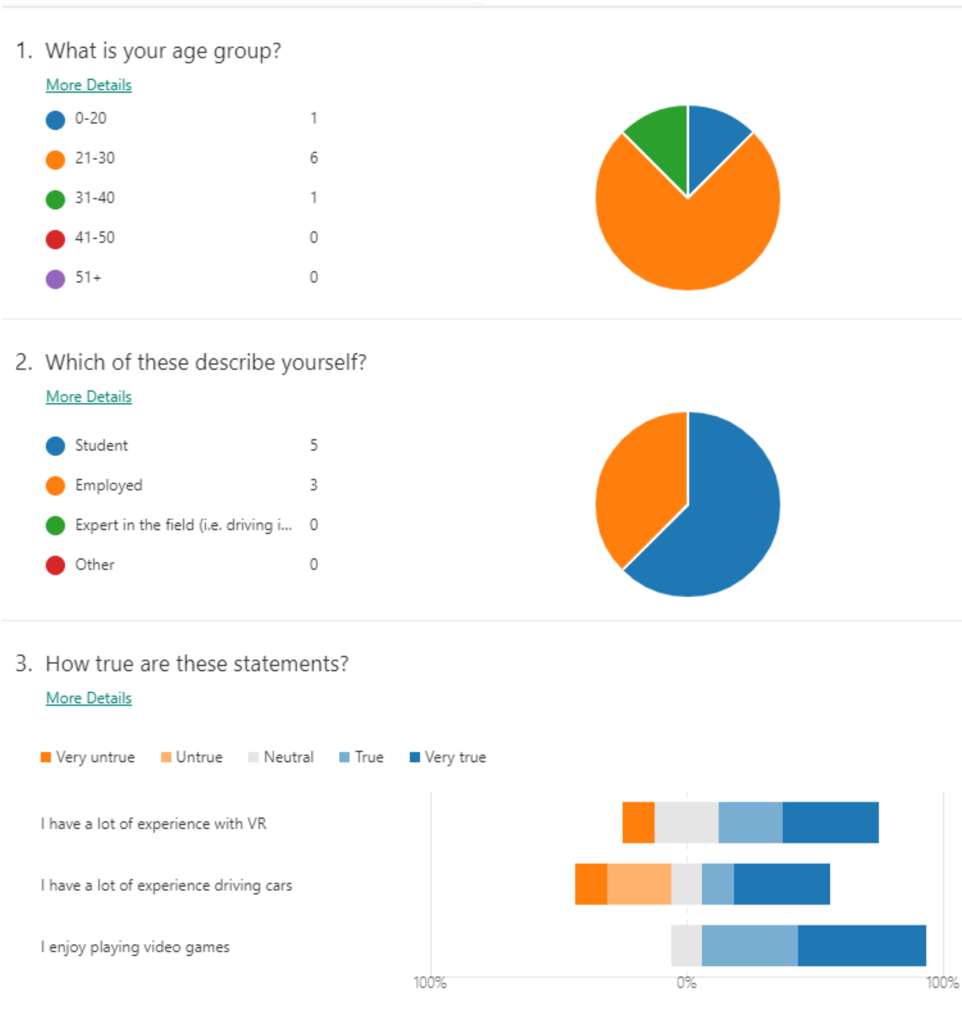
- Yes
- No

16. If you tried it, did you like the drift mode. Did you find it fun?

- Yes
- No
- Maybe
- Other

Appendix B

Questionnaire answers


1. What is your age group?
More Details
0-20 1
21-30 6
31-40 1
41-50 0
51+ 0
2. Which of these describe yourself?
More Details
Student 5
Employed 3
Expert in the field (i.e. driving i... 0
Other 0
3. How true are these statements?
More Details
Very untrue
Untrue
Neutral
True
Very true
I have a lot of experience with VR
I have a lot of experience driving cars
I enjoy playing video games
100%
0%
100%

4. Have you passed a dark driving course? (Trafikant i mørket/Mørkekjøring)

More Details

Yes	3
No	5

5. Did you play the game with a VR headset or watch the video playthrough?

More Details

VR headset	8
Video	0

6. What language did you play the game in?

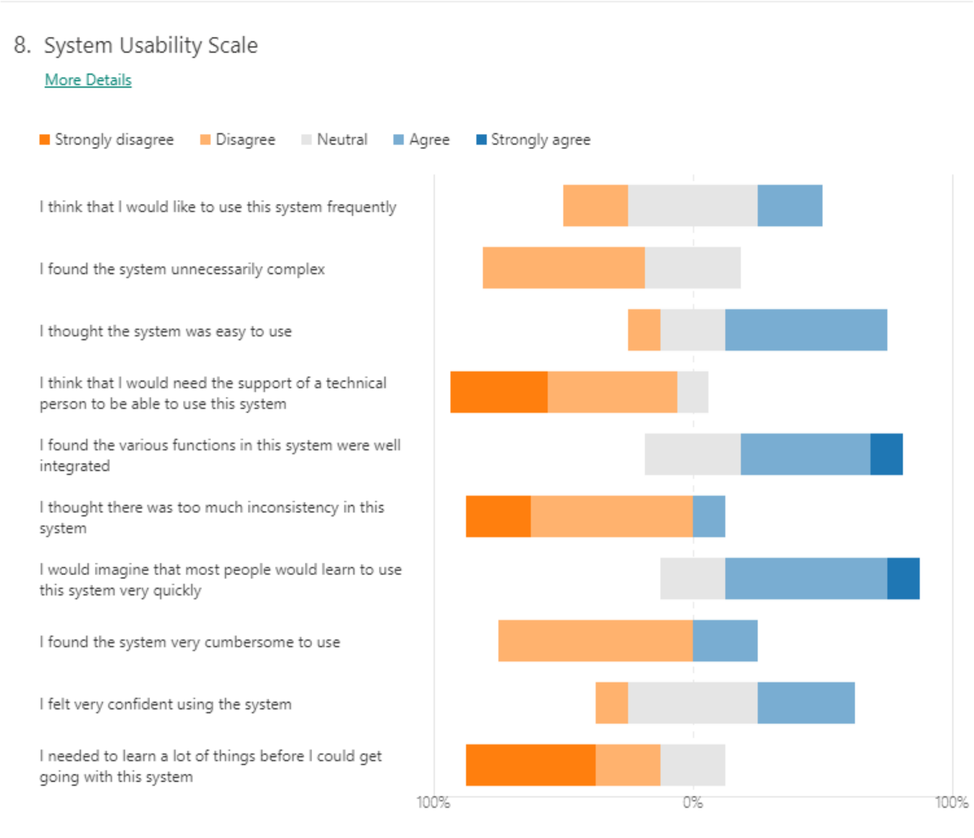
More Details

Norwegian	1
English	7

7. What VR headset (and controllers) did you use?

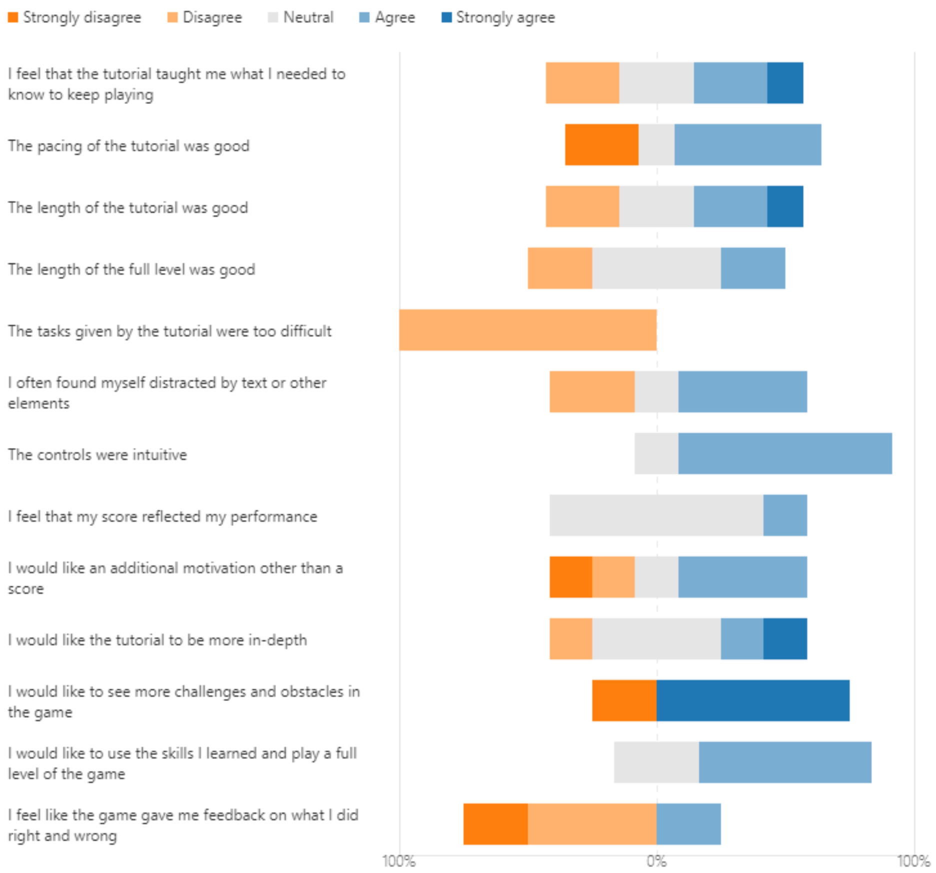
More Details

Oculus Rift	5
Oculus Quest	0
HTC Vive	3
Valve Index	0
HP Windows MR Headset	0
Other	0


8. System Usability Scale
More Details
Strongly disagree
Disagree
Neutral
Agree
Strongly agree
I think that I would like to use this system frequently
I found the system unnecessarily complex
I thought the system was easy to use
I think that I would need the support of a technical person to be able to use this system
I found the various functions in this system were well integrated
I thought there was too much inconsistency in this system
I would imagine that most people would learn to use this system very quickly
I found the system very cumbersome to use
I felt very confident using the system
I needed to learn a lot of things before I could get going with this system
100%
0%
100%

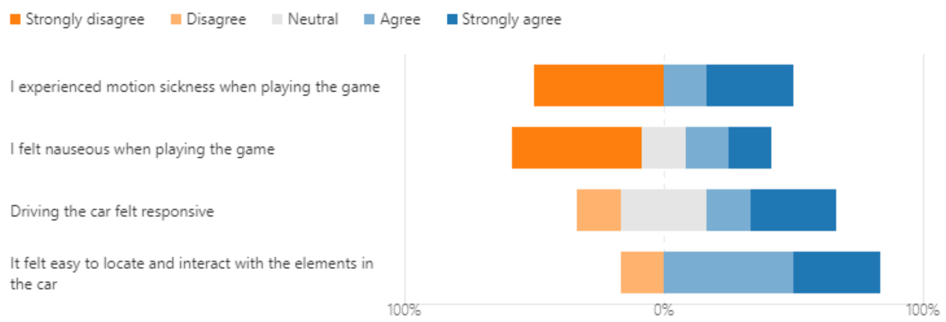
9. If you only watched the video, answer these based on your assumptions and perception

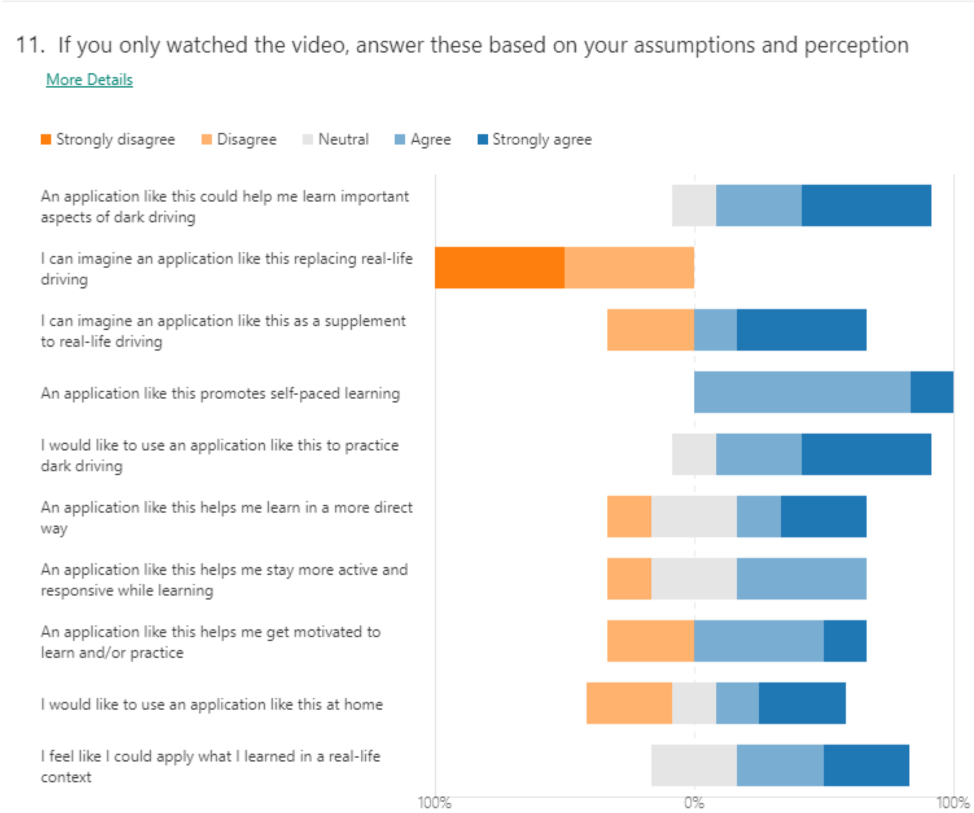
More Details



10. If you only watched the video, answer these based on your assumptions and perception

More Details

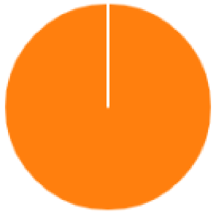



11. If you only watched the video, answer these based on your assumptions and perception
More Details
Strongly disagree
Disagree
Neutral
Agree
Strongly agree
An application like this could help me learn important aspects of dark driving
I can imagine an application like this replacing real-life driving
I can imagine an application like this as a supplement to real-life driving
An application like this promotes self-paced learning
I would like to use an application like this to practice dark driving
An application like this helps me learn in a more direct way
An application like this helps me stay more active and responsive while learning
An application like this helps me get motivated to learn and/or practice
I would like to use an application like this at home
I feel like I could apply what I learned in a real-life context
100%
0%
100%

12. Would you prefer a voice reading the tutorial steps?

More Details

Yes, only voice	0
Yes, voice and text	8
No, only text	0



13. Would you like a better explanation of your score?

More Details

Yes	8
No	0

14. Did the game feel too complicated?

More Details

Yes	2
No	6

15. Did the darkness simulation feel realistic?

More Details

Yes	6
No	2

16. If you tried it, did you like the drift mode. Did you find it fun?

More Details

Yes	2
No	1
Maybe	1
Other	0

Appendix C

Interview guides

C.1 XR.Tech Conference Interview guide

High level: Make sure to ask about potential. It is an early prototype and doesn't look like much yet. If players drive into the ice area, ask about ice driving. Would they be interested in using something like this? Why/why not?

Questions to ask:

- What are your first impressions?
- Do you have much experience with VR?
- Did you find the car and its controls responsible?
- Did you have trouble seeing where you were going?
- We're developing this into a game to help learn night driving, do you believe VR can be a good tool to support that?
- What would you like to see in such a tool/game?
- Did you feel like your score reflected what you did?
- Did you experience any motion sickness?

C.2 Interview guide for iteration 2

High level: Remember that these are IMTEL students with prerequisite VR knowledge See if they have fun, ask what they liked/didn't like Remember to point out the hazard and see if they understand how it works

questions:

- What are your first impressions?
- Did you have any problems locating the controls?
- Do you think the gaze mechanic has potential?
- What do you think your score means? What do you think you should be rewarded for?
- What would you like to see in the future for this game?
- Did you experience any motion sickness?

C.3 Interview guide NPRA iteration 2

High level: Remember to showcase the hazard and gaze mechanics Ask for some factual info: Need to know safe speeds Remember to share own vision, ensure we are in agreement

- What do you think of the direction we've moved towards?
- What would you like to see more of, what would you like to see less of?
- Do you feel the gaze mechanic is a good way to represent a driver's perception?
- Do you agree with how the scoring works? (elaborate)
- Where do you imagine this game next time we meet? (share own thoughts)

C.4 Interview guide Wright Trafikkskole

Are they familiar with our concepts? Gamification, serious games, VR Bring controllers - let them try them Show demo if they have questions

- What do you think of VR technology and simulator usage for driver education? Do you have any experience
- Are there any specific cases where you think VR technology/simulators have value in driver education
- Are there any specific subjects or concepts you think are difficult to teach to new drivers?
- What do you think of the concept of what I've made, a VR game for night driving?
- What do you think of having a point-system that rewards players for showing traffic skills? (show demo)
- What do you think of the way I've used controllers? Would you prefer a steering wheel?
- Would you consider using this yourself at your driving school?
- Have you done any remote learning due to Covid?
- Do you have any suggestions on how to improve this?

Appendix D

Textual walkthrough of tutorial

This is a step-by-step textual walkthrough of the final prototype's tutorial level.

- The player starts off inside a box, and is shown a text how to proceed. Press the green button to start, or the blue to skip the tutorial
- Upon pressing the green button, the world is visible to the player. They receive a message welcoming them to the tutorial
- The player is first instructed to grab the steering wheel by their right hand, and rotate the steering wheel clockwise
- Once the steering wheel has been rotated 90 degrees clockwise, they are instructed to grab it by their left hand and rotate it counter-clockwise.
- Upon completion, they are tasked to grab it using both hands at once, and rotate it in either direction
- The shift lever begins to glow, and the player is told to grab it and change gear to drive
- Optional: If the player pulls the shift lever towards them, changing the gear to reverse, they get a message telling them to try the other way
- Once the player has moved the shift lever forward, putting the car in drive, they are instructed to use the gas pedal
- The trigger button on the right controller is highlighted
- Once the player reaches 30 km/h, the trigger button on the left controller is highlighted instead, and they are asked to brake
- When the car has stopped, they are told to keep driving until they reach a marked point
- The player drives not far ahead and will notice a bright blue area marker
- Upon parking the car inside this marker, the score counter is made visible
- The player receives instructions telling them that their performance is monitored
- "We're keeping track of your score, and your speed"
- "Drive a distance and see if you can stay around 50km/h"
- The player can then follow the road for around 700m. The road offers some slight challenge with curves.

- As the player was instructed to stay around 50km/h, that is the optimal speed for the cumulative speed score, and keeping this speed will gain them the most points.
- Before they reach the next checkpoint, the player can see two hazards, in the form of deer, on their way.
- After reaching the next checkpoint, the player will get different messages depending on their drive. If they gained a big score, the messages will be more positive. Additionally, if they noticed any of the hazards on the way, it will be pointed out to them
- The player is given messages explaining how their score is calculated by several factors, such as their speed and their ability to notice hazards
- The long light toggle begins to glow, like the shift lever did before, and the player is instructed to press the interact button to interact with it
- Once the player does so, they can see a moose standing right ahead of them, not far away
- This moose is intended to showcase how limited your vision is without having your long lights active
- The player is instructed to look at the moose, and after 5 seconds, the moose will walk off to the side. The player receives 5000 bonus points
- The player can then keep driving
- About 400m further down the road, the player enters icy roads
- The car is now losing friction a lot easier
- The player receives a message advising them to slow down. They are told that staying around 30km/h should be safer
- As the player drives around a tricky corner, they see the next checkpoint
- Upon entering this checkpoint, the tutorial is over and they can try out the larger level

Appendix E

Links to the prototype

Distribution website: https://vrdarkdriving.carrd.co

Google Drive link to executable build of the prototype:
https://drive.google.com/drive/folders/1c4y7dii4xzCrIMDZsu-SPwul5S_cE-p2

Google Drive link to video walkthroughs:
https://drive.google.com/drive/folders/1CVIZaoCH6vcxIbczlOOWVeJBfwUjtffw

Appendix F

Consent form

Taking part in the research project

"Immersive Technologies for Learning and Training"

This is an inquiry about participation in a research project where the main purpose is to to explore the potentials and limitations of Immersive Technologies (virtual/mixed/augmented reality, VR/MR/AR) for learning and training in different areas, as a part of master student projects at Innovative Technologies for Learning (IMTEL) VR lab. To conduct this research, we will need to investigate the development and use of immersive technologies for learning and training in various contexts, including learning of language and mathematics, visualization of climate change, immersive exploration of historical manuscripts, workplace training and visualization of medical procedures. In this form we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
To conduct this research, we will need to analyze the use immersive technologies for learning and training in various contexts, including learning of language and mathematics, visualization of climate change, immersive exploration of historical manuscripts, workplace training and visualization of medical procedures. The goal is to develop innovative learning methods and tools using immersive technologies.

Who is responsible for the research project?
NTNU, Department of Education and Lifelong learning is the institution responsible for the project.

Why are you being asked to participate?
You are asked to participate because you are a potential user of educational applications developed as a part of this project and have visited our lab/expressed interest in immersive technologies. Your feedback is important for develop innovative learning methods and tools.

What does participation involve for you?
You will be ask to test immersive applications for learning and training purposes and then give feedbacks in the form of questionnaires and interviews/group interviews.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act). Any data that can be traced to individual participants will be kept confidential and anonymized before being used for research purposes. Parts of the sound recordings will be transcribed (written down) and stored electronically. All source data will be handled and stored in accordance with the existing regulations by NTNU as the responsible institution and only persons associated with the project (IMTEL VR lab research personnel and master students) will have access to them.

What will happen to your personal data at the end of the research project?
The project is scheduled to end 31.12.2020. All data will be anonymized at the end of the project, e.g. audio and video will be deleted when transcripts and analysis of data are completed, except for selected video and photo material to be used for research purpose. These and anonymized recordings from the inside of the virtual environments may be used for demonstrations in research context in such a way that no information will be linked to individuals. Scientific reports and presentations from this study might contain recordings from the VR/MR/AR sessions, questionnaire results, anonymized photos/videos from the sessions and anonymized citations from the interviews.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with NTNU, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:
- Ekaterina Prasolova-Førland (Department of Education and Lifelong Learning, NTNU)
- phone: +47 99 44 08 61, email: ekaterip@ntnu.no
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Consent form

I have received and understood information about the project **Immersive Technologies for Learning and Training** and have been given the opportunity to ask questions. I hereby declare my consent that my data in relation to Immersive Technologies for Learning and Training may be stored, documented and used for research and educational purposes as described above. I give consent for my personal data to be processed until the end date of the project, approx. 31.12.2020

(Signed by participant, date)

Appendix G

List of Unity Asset Store assets used

SteamVR plugin: *https://assetstore.unity.com/packages/tools/integration/steamvr-plugin-32647*

Car with Interior 15: *https://assetstore.unity.com/packages/3d/vehicles/land/car-with-interior-15-132073*

Road props - low poly: *https://assetstore.unity.com/packages/3d/props/exterior/road-props-low-poly-123340*

Easyroads 3D Free v3: *https://assetstore.unity.com/packages/3d/characters/easyroads3d-free-v3-987*

Deer, caribou and moose: *https://assetstore.unity.com/packages/3d/characters/animals/deer-caribou-and-moose-55147*

Trees: *https://assetstore.unity.com/packages/3d/vegetation/trees/trees-93921*

PBR dirt and ground materials #1: *https://assetstore.unity.com/packages/2d/textures-materials/floors/pbr-ground-materials-1-dirt-grass-85402*

Stian Sørli

Towards a driving license in VR

NTNU

Norwegian University of
Science and Technology