EnviroCircuit

Designing Immersive VR Racing Experiences for Different Levels of Player Experience

Master's thesis in Computer science and engineering

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Cover: The three unique environments that were created. The City track (top left), the Forest Track (top right), and the Space track (bottom centre).

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Abstract

This thesis explores how to design immersive virtual reality (VR) racing experiences for different levels of player experience. The thesis follows an iterative design process that involves discovering, designing, prototyping, and evaluating three different VR racing prototypes. The thesis presents a set of guidelines for designing immersive VR racing experiences and a functional prototype. The guidelines can be considered by future researchers and designers when wanting to develop immersive racing experiences, and as a result make these experiences more easily accessible for people with various amounts of experience with virtual racing.

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Introduction

As Virtual Reality technology increases in popularity, so does the importance of research into its effect on individuals using it. One of the common effects Virtual Reality has is the feeling of being immersed in the experience. According to Jennet *et al.* [1], immersion has three impacts on the individual: lack of awareness of time; loss of awareness of the real world; involvement and a sense of being in the task environment. Furthermore, the authors also state that "immersion is key to a good gaming experience". From this we can say that immersion is an important criteria to meet when designing experiences.

This thesis will be done in collaboration with Lynk&Co's Prospective Design team [2] to examine what should be considered when designing an immersive experience in the racing genre specifically.

1.1   Purpose

This thesis will go through how one can design and implement a racing experience in such a way as to have a high amount of immersion for people with a variety of experience levels. This is to let as many individuals experience the feeling of immersion as possible, thus also increasing the accessibility and quality of the experience. This gives us the projects research question which is:

> *What should be considered when designing a virtual reality racing experience to increase the feeling of immersion for a variety of experience levels?*

The final result will thus include a comprehensive set of guidelines, as well as the final functional digital prototype, aimed at addressing the research problem at hand.

Knowing what one needs to consider when designing for a variety of players will help with getting a better understanding of what aspects of the experience are important to include, or not to include to get the feeling of immersion. This will make it easier for designers to know what to consider when wanting to develop immersive racing experiences, and as a result make these experiences more easily accessible for people with various amounts of experience with virtual racing.

1.2 Limitation

Because this study has to be done within a certain time frame, there will be some limitations. Firstly, the outcome will purely be in the form of guidelines and a prototype, no quantitative analysis will be done from the test results. Second, the evaluated experience will be limited to a single player experience only, no computer or human controlled characters and their effect on the player will be studied. The player will only be able to drive around a closed track and not in an open-world environment. As for the hardware, the study will only consider the experience being in Virtual Reality (VR), it will not look at any other emergent technologies such as Augmented Reality (AR) or Mixed Reality (MR) or the differences between them. Furthermore, the prototype will be implemented to work for computers only, it will not be designed for console, mobile, or handheld devices. Lastly, the user group that will be studied will be between the age of 18 and 55.

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Background

This chapter introduces the main stakeholders involved in the thesis. It also describes some examples of existing racing games in different sub-genres and their features and characteristics.

2.1 Stakeholders

There are a total of three main stakeholders for this thesis project. Each of them will be given a brief description of their background and why they are considered a stakeholder.

Lynk & Co

This automotive brand can best be described from the following quote taken from Lynk&Co's [2] parent company Geely's own website [3]:

> *LYNK & CO is a global automotive brand formed as a joint venture between Geely Auto Group and Volvo Car Group that dares to challenge the established automotive industry with an offering that meets the needs and requirements of a new generation of globally connected consumer.*

Lynk & Co is on a quest to turn the automobile industry upside down by making mobility more flexible and hassle-free with their competitive car subscription prices [2]. Not only that, they are going above and beyond to give their customers the "wow" factor.

Currently, Lynk & Co's Prospective Design team is exploring areas outside the automobile industry, one being gaming experiences such as virtual racing. They are looking into how one can design and develop an immersive racing experience and they have given the task of exploring this with them to university students.

The Author

The author of this report, Rik Muijs, is singularly responsible for all components in this study. These responsibilities include, but are not limited to: design, development and evaluation of the prototype; creation of guidelines; writing of the thesis report; communication and collaboration with relevant individuals or organisations.

Chalmers University of Technology

This study will be done within Chalmers University of Technology [4]. The university has their own set of requirements and deadlines which are expected to be met in order for it to be counted as completed [5]. Chalmers will support this study by supplying an academic supervisor and examiner who will ensure the process and results of the study are as high quality as possible. Chalmers might also support this study through financial contributions such as the purchase or letting of equipment or digital assets.

2.2 Sim Racing Games

Sim racing is a sub-genre of racing games which focus on making the racing experience as realistic as possible. Noteworthy sim racing games include iRacing [6], rFactor 2 [7], and Live for speed [8] and will be described further in Section 2.2.1, 2.2.2, and 2.2.3 respectively.

2.2.1 iRacing

The following section is taken from the iRacing website [6]:

> *iRacing puts you in the driver's seat by allowing members to experience today's newest form of competitive motorsport: virtual racing. iRacing is a fun, inexpensive and highly-competitive way for race fans and gamers to break a sweat by braking hard at the apex, while overcoming head-to-head racing challenges usually reserved for professional racers.*

iRacing is a subscription based service created for competitive racing. It includes more then 100 tracks and vehicles for players to choose from. Players pay a monthly fee in order to race against other players and compete in leagues. The game is also compatible with VR headsets. An image of someone playing iRacing can be seen in Figure 2.1.

2.2.2 rFactor 2

The following text was taken from the rFactor website [7]:

> *The newest creation, rFactor 2, creates a dynamic racing environment that for the first time puts you the driver into a racing simulator, instead of just a physics simulator. Changing tires, track surfaces, grip, weather and lighting make rFactor 2 a true challenge to any sim racer.*

rFactor 2 is the second installment of the rFactor series and available for a set price. It offers online racing against other players and offline racing against Artificial Intelligence. There are numerous vehicles and tracks available for the player to download. It has high-end graphics and audio, with the addition of VR support. An in game screenshot of rFactor 2 can be seen in Figure 2.2.

Figure 2.1: iRacing [6]

2.2.3 Live for speed

'Live for Speed is a serious racing simulator. No arcade modes, no steering aids - YOU have to do the driving.' [9].

Live for speed is a free sim racing game, it offers realistic vehicle physics and sounds with the addition of VR support. However, it does not have high quality graphics. Players can play on one track and choose between three free vehicles, additional vehicles and tracks are available for purchase.

2.3 Arcade Racing Games

Arcade style racing games are another sub-genre of racing games, these are racing games of the style played on old-school arcade machines. These games are less realistic but instead focus more on a fun and fast-paced experience. Typical features for these types of games are power-ups to boost the speed of the vehicle, ramps on the track, and abilities that sabotage the other players on the track to give you an advantage. Some examples of arcade racing games are games from the Mario Kart™ franchise such as Mario Kart™ 8 Deluxe [10] or Need for Speed™ Unbound [11] from the Need for Speed™ franchise. These two games will be discussed in Section 2.3.1 and 2.3.2 respectively.

Figure 2.2: rFactor2 [7]

2.3.1 Mario Kart™ 8 Deluxe

Released on the Nintendo Switch in 2017, Mario Kart 8 Deluxe is currently the latest Mario Kart game in the franchise. It offers 48 courses, 40+ characters, and allows for up to 12 players to compete against each other [10]. During the race, the players can use different items which can help them get the upper-hand over their opponents. An image of Mario Kart™ 8 Deluxe can be seen in Figure 2.3

Figure 2.3: Mario Kart™ 8 Deluxe, image taken from Nintendo's website [12]

2.3.2 Need for Speed™ Unbound

The following description has been taken from EA's[1] website [11]

> *Race against time, outsmart the cops, and take on weekly qualifiers to reach The Grand, Lakeshore's ultimate street racing challenge. Pack your garage with precision-tuned, custom rides and light up the streets with your style, exclusive fits, and a vibrant global soundtrack that bumps in every corner of the world.*

Need for Speed™ Unbound stands out with its unique visual style by mixing realistic-with cartoon style graphics. An example of this visual style can be seen in Figure 2.4. The game lets the player embark on a journey through an open world. The player can do various activities such as exploring the open world, racing against other vehicles, or trying to escape the police. Races often happen right in the middle of the city, so the player will have to act quickly by dodging traffic, pedestrians, and buildings.

Figure 2.4: Need for Speed™ Unbound, image taken from EA's website [13]

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[1]Electronic Arts (EA) is the interactive entertainment software company who created Need for Speed™ Unbound

3

Theory

This chapter will go through important and relevant theories for this thesis. These include: immersion, flow, presence, dynamic difficulty adjustment, and virtual reality. The difference between immersion, flow, and presence will also be briefly described.

3.1 Immersion

Let us start by defining what an immersive feeling actually means. In its most basic form, according to Jennet *et al.* [1] immersion is the extent to which a person's attention is focused on the game. The authors further define immersion by stating that it produces the following effects: lack of awareness of time; loss of awareness of the real world; involvement and a sense of being in the task environment. Furthermore, Brown [14], explored a grounded theory on immersion and states that levels of involvement with a game can be seen in three distinct degrees: engagement, engrossment, and total immersion.

A taxonomy dividing immersion along three orthogonal dimensions also exists to better differentiate the different uses of immersion [15]. These dimensions being: immersion as a property of the system; immersion as a response to an unfolding narrative, the diegetic space, or virtual characters; and immersion as a response to challenges demanding use of one's intellect or sensorimotor skills.

There are two main ways to measure immersion, namely through questionnaires [1], [16] or physiological signals [17]. Looking more closely at the structure of the questionnaires, Jennett *et al.* [1] divide the questions into eight distinct categories. These categories are: basic attention, temporal dissociation, transportation, challenge, emotional involvement, and enjoyment. On the other hand, Qin *et al.* [16] divides these into the following categories: curiosity, concentration, challenge and skills, control, comprehension, and familiarity. The differences of these questionnaires could lay in the method each of the authors used in their studies. For example, Jennet *et al.* had participants do tasks in an immersive, or a non immersive task, and afterwards fill in their questionnaire, which was later evaluated. Qin *et al.* on the other hand asked participants to 'imagine a familiar game with a story frame while answering the questions about player immersion in the computer game narrative' [16, p.119]. This could suggest that Jennet *et al.* had a more sophisticated

approach to the creation of the questionnaire.

3.2 Flow

The concept of flow has been extensively studied by Csikszentmihalyi [18]. According to his studies 'flow is a subjective state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself' [18, p.230]. Furthermore in order for someone to get into flow, Csikszentmihalyi concluded that three main conditions have to be met. Firstly, the activity needs to contain a 'clear set of goals'. Secondly, there needs to be 'a balance between perceived challenges and perceived skills'. Finally, there needs to be 'clear and immediate feedback' [18, p.232]. In the second condition, if challenges exceed the person's skills it will result in anxiety and if skills exceed the challenge, it will result in boredom [18]. A visual representation of this described concept can be seen in Figure 3.1. It is thus important to keep a good balance between challenge and player skills in order for the player to feel the sense of flow. Further information regarding game challenge is discussed in Section 3.5.
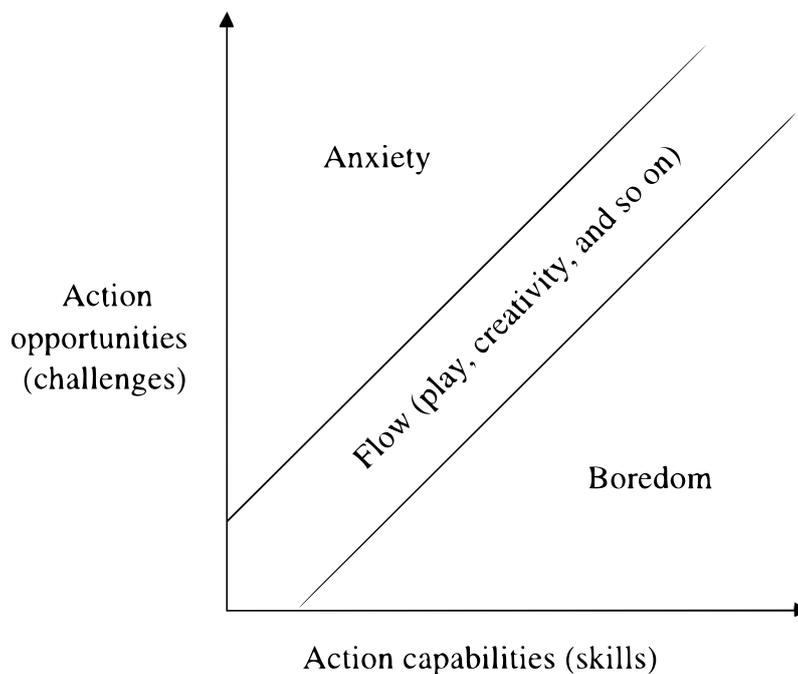
Figure 3.1: The concept of flow. One can see from the figure that when challenges exceed the person's skills it will result in them feeling anxiety. On the other hand, if skills exceed the challenge, it will result in the person feeling boredom

3.3 Presence

According to Witmer and Singer [19] 'presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another'.

Felton and Jackson [20] state that presence consist of two core dimensions: spatial presence and social presence. The authors state that 'spatial presence refers to the subjective sense that one is physically located within the perceived environment and subject to any physical consequences therein'. While 'Social presence refers to the degree to which another animate entity appears to coexist in the same environment as the user'.

3.4 Comparing immersion, flow, and presence

Immersion has been compared with similar concepts such as flow and presence [15], [21]. Michailidis *et al.* [21] state that flow and immersion do not appear as conceptually distinct and can be used interchangeably, however, presence and immersion are not the same as presence is enveloped in immersion. We can clearly see that presence is enveloped in immersion as one of the main features of immersion - the sense of being in the task environment - is incredibly similar, if not identical, to the concept of spatial presence. Mechailidis *et al.*'s view on the difference between flow and immersion clashes against that of Jennett *et al.* [1]. Jennet *et al.* argue that, even if a game does not have a clear goal or direct feedback - the two conditions that have to be met in order for someone to experience flow - it can still be capable of giving the individual an immersive experience.

3.5 Dynamic Difficulty Adjustment

To give the player an appropriate challenge, one first has to know the skills that player holds. This is commonly done with pregame profiling with, for example, a selection of difficulty levels [22]. However, this neglects the fact that the player is a dynamic entity and will adapt to the selected difficulty [23], [24]. Dynamic difficulty adjustment (DDA) thus aims to solve this problem, by dynamically changing the difficulty during the course of the game. There have been different papers studying DDA on experiences and games [24]–[26]. DDA has been shown to improve the gaming experience. For example, Paraschos and Koulouriotis [26] state that 'the players favor the dynamic game environments over the static ones, as they can offer them more challenging tasks and therefore improve their overall gaming experience' [p.13]. Furthemore, Paraschos and Koulouriotis also state that numerous studies suggest that 'the players feel more immersed when the game content or environment is adapted or personalized according to their exhibited emotions' [p.13].

DDA relies on knowledge of the player skill level and game difficulty, this difficulty is then dynamically changed in order to match the player abilities. We will now look further into the ways in which player abilities and game difficulty are usually measured. Note that the player skill is enveloped in the difficulty of the game, this is because the way the player perceives the difficulty is dependent on their skill. There is therefore an overlap of definition between measuring player skill and game difficulty.

Dziedzic [24] suggests there are three ways to measure the difficulty of a game: using

the formal model of gameplay, using the features of the game, and direct examination
of the player. When using the formal model of gameplay, 'DDA systems are based
on the analysis of the structure of the game tree' [24, p.709]. The nodes of the game
tree contain each possible state of the game, with each edge representing if the
player can reach that state within one action. This method of evaluating difficulty
is suitable in, for example, a board game such as chess, as these types of games are
predictable and thus suitable to be modelled into game trees. An example of using
the formal model of gameplay on a game of Tic-Tac-Toe can be seen in Figure 3.2.
The second way - using the features of the game to determine difficulty - is used
'where the formal model is not known or it is too complicated to it – due to a large
number of moves the player can make it is not possible to create a full game tree' [24,
p.709, 710]. Here we can use both characteristics from game elements and player
performance to evaluate the difficulty. For game element parameters, this could for
example be the number of enemies alive in a shooter game. For player performance
characteristics, this could be the percentage of time that the player is off the track,
and the average speed of the car in a racing game [27]. For parkour games, player
performance characteristics can be the amount of obstacles the player has passed
[28]. Lastly, direct examination of the player is where 'designers of DDA systems
analyze the difficulty perceived by the player instead of elements of the gameplay'
[24, p.710]. One could for example do this with the examination of physiological
signals [17].
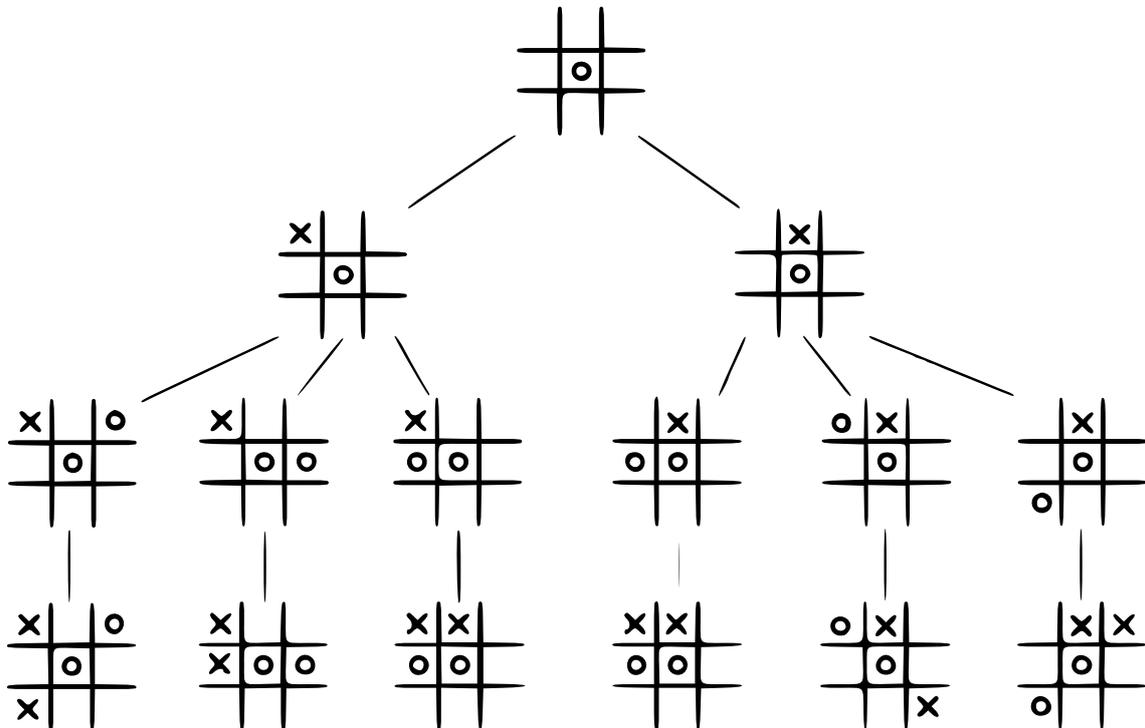
Figure 3.2: An example of the game Tic-Tac-Toe being made into a game tree.
The nodes represent the state of the game, while the edges represent if the player
can reach the given state within one action image taken from Gobet *et al.* [29, p.13]

3.6   Virtual Reality

In short, 'Virtual Reality (VR) is an advanced, human-computer interface that simulates a realistic environment' [30]. Its 'central objective is to place the participant in a virtual environment that gives the participant a feeling of "being there."' [30]. This is done by wearing what is called a Head Mounted Display (HMD). There have been numerous studies stating that VR has a positive effect on immersion [31], [32]. However, one major problem with VR is that it can cause so called "cybersickness". [33]. Rebenitsch and Owen state that the most common source of cybersickness is sensory mismatch. This is where 'stimuli from the outside environment [is] being perceived differently by different senses' [33, p.105]. Furthermore, Saredakis *et al.* [34] found that gaming content induced the highest amount of sickness.

4

Methodology

This chapter will go over the different methodological concepts that are relevant for this study. Starting with describing the process of Interaction Design, according to Sharp *et al.* [35] this process can be divided into four basic phases, namely, discover, design, prototype, and evaluate [35, p.50]. A similar process is described by Cooper *et al.* [36], namely, Research, Modeling, Requirements Definition, Framework Definition, Refinement, and Support. Although Cooper *et al.*'s process is more extensive, Sharp *et al.*'s phases are more suitable for smaller projects as they focus on less formal requirements such as modeling user behavior or defining system behavior. Looking at the design process for games specifically, Fullerton's [37] process is quite similar to that of Sharp *et al.* Fullerton describes the process with the following steps: Brainstorming, Physical Prototype, Presentation, Software Prototype, Design Documentation, Production, and Quality Assurance. All of these processes have iteration at their core. The concept of iterative design is taken up in Section 4.5
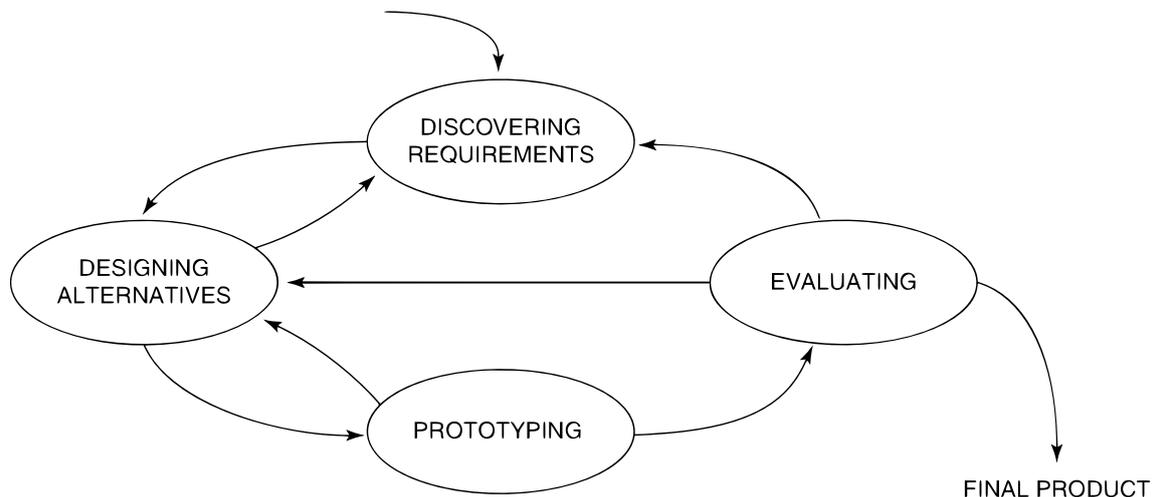
Figure 4.1: The relationship between the four basic phases of Interaction Design. Taken from Sharp *et al.* [35, p.52]

We will now go into further detail about the four phases proposed by Sharp *et al.* A visual representation of how these four phases relate to each other can be seen in Figure 4.1. Firstly, the discovering phase includes activities that help build under-

standing of the target user and scenario by creating requirements for the product. Common activities used in the discovering phase are interviews, questionnaires, and observations, see Section 4.4.1, 4.4.2, and 4.4.3 for more information regarding these activities. The design phase is where the requirements are met by creating a possible design solution, more information about the design phase can be found in Section 4.2. The prototyping phase is where the previously created designs are made tangible, Section 4.3 will go into more detail about prototyping. Finally, the evaluating phase is where one or several prototypes are tested by users and evaluated based on the users experience with the prototype. The same activities from the discover phase are commonly used in the evaluation phase as well. The evaluation phase will be taken up in Section 4.4.

4.1 Discovering

The discovering phase is all about exploring the problem space and defining requirements for the product. In short, the problem space is the area in which we define the problems that we want to solve [38]. While a requirement can be defined as 'a statement about an intended product that specifies what it is expected to do or how it will perform.' [35, p.387]. Sharp *et al.* also state that another way to specify what a product is expected to do is by defining a user story. A similar concept mentioned by Fullerton [37] is "experience goals". She defines this as 'goals that the game designer sets for the type of experience that players will have during the game' [37, p.12]. Sharp *et al.*'s definition of requirements can be compared with Fullerton's [37] definition of experience goals, as in essence, they both try to answer the same question, that being what outcome one wants with a certain artefact. In the case of Sharp *et al.* this artifact is the design, while for Fullerton it is the game.

A common activity that can be done to explore the problem space is conducting a literature review. In short, according to Knopf [39], 'a literature review summarises and evaluates a body of writings about a specific topic'. This is important to do when carrying out a study about a specific topic, as one can get insights about what research has been - or has not been - previously done. This is a vital part as the aim of research studies is to contribute to existing knowledge [39].

4.2 Design

The design and prototyping phase discussed in Section 4.3 can either be seen as two separate phases or as one whole phase. This is because, essentially, they are both about finding solutions to the requirements or experience goals which were created in the previous discover phase. The design phase can be seen as an activity where a document of high concept solutions of the requirements is created before going on to the prototyping phase. Sharp *et al.* [35] call this document a conceptional design and it describes 'what people can do with a product and which concepts are needed for the user to understand how to interact with it'[p.434]. Johnson and Henderson [40] describe conceptual models as 'a high-level description of how a

system is organized and operates' [p.26]. In the area of games, Fullerton [37] calls this a treatment or concept document. Fullerton states that 'a treatment does not go into great detail about every aspect or level of the game; however, it will address [the] top-level questions about the idea' [p.190]. The conceptional design can include things such as metaphors, analogies, concepts, relationships, and mappings [40]. As for games, it can also include game mechanics.

4.3 Prototyping

The prototyping phase is where a more concrete, tangible artefact is made which meets the requirements of both results of the discover and the design phases. After completion, the prototype is evaluated with the user, the evaluation phase will be covered in Section 4.4. A prototype can either be of low or high fidelity (called lo-fi and hi-fi respectively). For exmaple, a lo-fi prototype may be made with paper or cardboard and offer a lower amount of functionality, while a hi-fi prototype could, for example, be a digital program which will have more functionality. Both hi-fi and lo-fi prototypes have their pros and cons, and each have their respective purposes. Benyon *et al.* [41] describe both in great detail, stating that low fidelity prototypes require little effort to put together; 'they are designed to be produced quickly, and thrown away as quickly' [41, p.256]. This makes it suitable for creating lots of different variations of the product which can then be communicated to and evaluated by users. High fidelity prototypes on the other hand are 'useful for detailed evaluation of the main design elements' [41, p.254]. Hi-fi prototypes are generally created later in the design process when the main design elements have been realised.

4.4 Evaluation

As Sharp *et al.* [35] describe it, the evaluation phase 'involves collecting and analysing data about users' or potential users' experiences when interacting with a design artefact such as a screen sketch, prototype, app, computer system, or component of a computer system' [p.496]. One should do this because the data that gets collected produces valuable information on what the target users think of the product that is being evaluated. There are several different data collection methods that can be used in the evaluation phase. Most common are interviews, questionnaires, and observations. These methods will be descirbed in Section 4.4.1, 4.4.2, and 4.4.3 respectively. The data collection method that is being used depends on what part of the artefact one wants to evaluate. Benyon *et al.* [41] propose the acronym IM-PACT; intention, metrics, people, activities, context, and technologies. These are six important aspects of the user evaluation one should consider before one starts evaluating. Firstly we have intention which is where one decides what the aim of the evaluation is. Second is metrics, this is where specifications are made about why, what, and how things will be measured. The third aspect, people, is where one decides what and how many users will be part of the evaluation. The fourth aspect is activities, this aspect concerns what, and in what order, the user will carry out specific actions during the evaluation. Fifth is context, which is where outside

variables such as social or physical aspects are considered. Lastly is technologies. What kind of hardware or other media that will be used during the evaluation is considered here. After each of these aspects are considered, Benyon *et al.* suggest writing a plan outlining the decisions made, and then conducting a pilot session to fix any potential issues. Pilot studies are described in Section 4.4.4

4.4.1 Interviews

If one is looking to collect qualitative data, interviews are a good activity to carry out. There are several different kinds of interviews, namely, unstructured, structured, and semi-structured [35]. In short, the difference between these types is how strictly the interviewer wishes to follow a certain schedule. Unstructured interviews typically have open-ended questions, and the interviewee is free to answer how thoroughly or shallowly they like. They can be compared to a more casual conversation, and the interviewer can decide to pivot the conversation to whatever they want to know more about. Unstructured interviews are useful for when one wants gain understanding in a specific type of topic [35]. During a structured interview, closed questions with a limited amount of available answers are asked. These questions are asked in the same order to each participant. The format of each question asked during a structured interview can be quite similar to the closed-ended questions in questionnaires. More information about questionnaires will be discussed in Section 4.4.2. The goal of structured interviews is to get answers about specific aspects of, for example, the design or the user experience. One can also later compare the answers and try to find patterns or relationships between them and the experience of the users. Lastly are semi-structured interviews, which combine both aspects of unstructured and structured interviews.

Interviews can for example be done after showing the target user a prototype to get information about what they though about it. In addition, they can also be done right after a questionnaire. Benyon *et al.* mention that: 'short individual interviews after testing are very valuable in clarifying user reactions, or amplifying the answers to questionnaire items' [41, p.281].

4.4.2 Questionnaires

A questionnaire is another way to collect data from users. In most cases, questionnaires are most useful when one requires quantitative data. There are different types of response formats that are common in questionnaires, for example, responses to close-ended questions can be 'yes' or 'no', or a rating from a scale that ranges from one to five [35]. The biggest difference between questionnaires and interviews is that when a questionnaire is made, it can be distributed to a substantial amount of users [35].

4.4.3 Observations

As Sharp *et al.* write: 'it can be difficult for people to explain what they do or to describe accurately how they achieve a task. It is unlikely that an interaction

designer will get a full and true story using interviews or questionnaires.' [35, p.288]. This is why observations are an important addition to an evaluation. Benyon *et al.* also support this, they say that 'you should complement interview and questionnaire data by observing people's activities as they happen' [41, p.222]. Observations help fill in the gaps that interviews and questionnaires leave by examining what users are doing during the course of the activity.

4.4.4 Pilot study

As Sharp *et al.* explain that 'a pilot study is a small trial run of the main study' [35, p.265]. The main objectives of a pilot study are to validate the feasibility of the study, and to allow the researchers to practise their role in that particular study [42]. For example, after a potential evaluation plan has been created, the researchers can first try out the evaluation themselves to test if it is appropriate and works smoothly.

4.5 Iterative Design

One of the most important aspects of interaction design is the fact that one does iterations of the process. Iterations make it possible for the design to be based on feedback from users [35]. In the concept of games, Fullerton [37] describes iteration as a process in which 'you design, test, and evaluate the results over and over again throughout the development of your game, each time improving upon the gameplay or features, until the player experience meets your criteria.' [p.16].

4.6 Scrum

A common agile project management technique called Scrum is a framework that helps people generate value through adaptive solutions for complex problems [43]. A typical scrum team contains a scrum master, product owner, and developers. Scrum activities include the planning, reviewing, and concluding of a Sprint. These activities will be taken up in more detail in Section 4.6.1, 4.6.2, and 4.6.3 respectively. A Sprint is a fixed length event typically lasting less than one month. During this time, all work necessary to achieve the product goal and other activities is done. One usually creates and maintains a list of all product improvements that can be done within a sprint. This list is called the Product Backlog and helps with keeping track of what has been done, and what still needs to be done within the project. Scrum works well as it splits big projects into smaller sub-projects which makes handling them easier.

4.6.1 Sprint Planning

Before each Sprint begins, one first needs to specify a development goal that needs to be met at the end of the Sprint [43], [44]. Schwaber and Sutherland [43] divide three main topics to take up during the planning phase. Topic one considers questions regarding how and why the product can increase in value during the Sprint. Topic

two is about deciding how much work will be done in the Sprint. This is done by selecting appropriate product improvements to work on from the Product Backlog. The last topic is about how the previously selected items will be developed. This could, for example, be done by dividing each item into smaller daily tasks.

4.6.2   Sprint Reviewing

A Sprint review is done after a Sprint has been finished [43], [44]. 'The purpose of the Sprint Review is to inspect the outcome of the Sprint and determine future adaptations' [43, p.9]. This is also an opportunity for the Product Backlog to be updated to represent the new implementations.

4.6.3   Sprint Retrospective

The last activity of a Sprint is called the Sprint Retrospective. This is where one looks back on the completed Sprint and reflect on the work that has been done. More specifically, the following questions are asked: what went well, what could be improved, and what will be improved in the next sprint [44].

5

Process

This chapter will go though the design and development process of the thesis. Firstly, the planning phase conducted at the very start of the project will be covered in Section 5.1. Then, the pre-study phase will be covered in Section 5.2. Finally, the three main phases will be covered in detail in Sections 5.3, 5.4, and 5.5. In each of these sections, design decisions, implementation specifications, and evaluation results will be described.

5.1 Planning

At the very start of the project, an initial planning phase was done. It was planned that the prototype was to be created in the Unity Game Engine. The prototypes two main components would be a race track and a car that could be controlled by a player. It was also planned that further components could be added to increase the immersion of the experience, this could for example be decoration or game objects that are added to the race track. The look of the car interior and user interface were also considered to be areas of interests, these areas could make room for further design decisions that could increase immersion.

It was also planned to do several evaluations throughout the development process. The evaluations would let the participants interact with the experience, this interaction could for example be driving a lap around the race track. After this, it was planned that the participants in the evaluation would be asked to fill out a survey which will measure how immersed they felt in the experience and why. The plan was that the participants in this evaluation should have varied experience levels. The aim of this was to see if there are any significant differences between their feeling of immersion.

A Gantt chart was also created that illustrated the planned schedule that would be followed for the thesis. This chart can be seen in Figure 5.1

5.2 Pre-study

A pre-study phase was done to get a better idea of the scope of the project and what needed to be included in the prototype to answer the research question. This
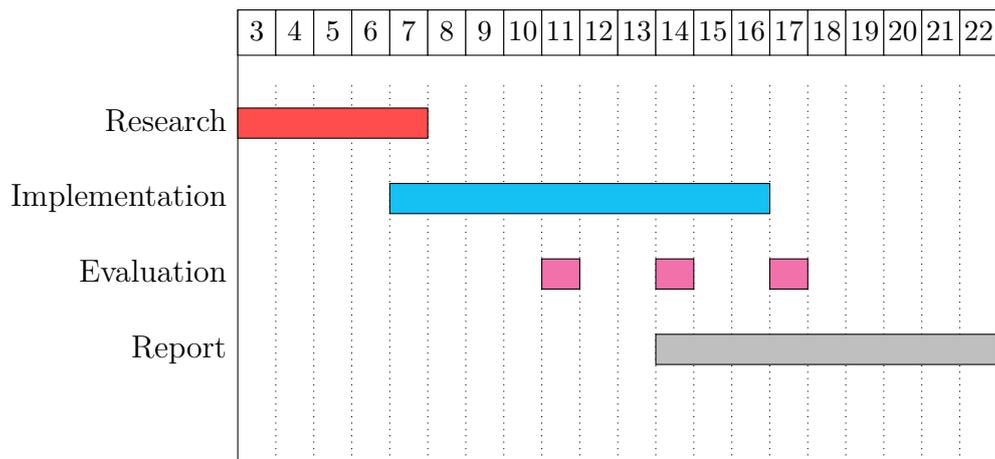
Figure 5.1: The schedule created at the start of the project

stage could also be seen as a first hypothesis, as during this time, it was not sure yet what factors would have the most effect on immersion. The pre-study phase was done as described in Section 4.1. This Section will go through the various different activities done in the pre-study phase. These activities include the literature review which will be covered in Section 5.2.1 and the project plan in Section 5.2.2 which will cover how the project was planned to be carried out in detail.

5.2.1   Literature Review

A literature review was done to get up to date with the most relevant theories, methodologies, and previous works such as similar immersive experiences including Sim racing and Arcade racing games. Previous works are taken up in Section 2.2 and 2.3.

As for researching relevant theories and previous works, specific keywords were used to search through literature database Google Scholar [45]. Examples of keywords used were: Immersion, Flow, Presence, Realism, VR, Racing, Dynamic Difficulty, and Games. Twenty one papers on the topic of immersion and eight on the topic of racing games were thoroughly examined.

Relevant methodologies were also studied. These included details of the design process such as the four phases: discover, design, prototype, and evaluate. The details of the scrum project management technique were also examined.

Research was also done on relevant implementation details. This was done by watching various YouTube videos related to different topics such as how to do different implementations, for example, how one can implement vehicle mechanics, and how to make a race track in Blender [46].

The results of the examined theories can be found in Section 3. The relevant examined methodologies can be found in Section 4.

5.2.2 Project Planning

The project was re-planned after the literature review. This was because relevant information was gained through it and thus an improved plan could be structured to better fit the goal of the project. It was planned that the project would follow the four previously stated activities of Interaction Design. These activities being, discovering (4.1), designing (4.2), prototyping (4.3), and evaluation (4.4). Furthermore, it was planned that the project would follow the agile project management technique Scrum discussed in more detail in Section 4.6. Details of how the initial requirements are planned to be created is taken up in Section 5.2.2.1. Then, the planned layout of the Scrum sprints will be discussed in Section 5.2.2.2. Finally, the planned way in which this study will be finalised will be covered in Section 5.2.2.6. An overview of the planned weekly activities can be found in the schedule in Figure 5.2.

5.2.2.1 Exploring initial requirements

In this subsection, the planned activities between weeks three and nine will be covered. Firstly, an initial research phase, followed by a discovering phase is planned to be done. The research phase includes a literature review of relevant topics such as immersion (3.1) and dynamic difficulty adjustment (3.5). The discovering phase (4.1) is planned to set product requirements, for example, this could contain setting experience goals and deciding which users will be included in the design process, as well as what environment it could be in. Part of this information may be supplied by and discussed with Lynk&Co (2.1).

The design phase (4.2) is planned to explore solutions to the requirements made in the discovery phase. This could include possible designs of visuals and gameplay. The visuals could include designs such as the user interfaces and visual styles. Gameplay designs could, for example, include game mechanics, track design, how dynamic difficulty is planned to be implemented, and vehicle behaviour.

5.2.2.2 Sprint layout

There are three Scrum sprints planned, each with a duration of three weeks. This will cover a total amount of nine weeks spanning weeks nine to eighteen. The start of a sprint is planned to change any requirements depending on the results of the previous sprint, this will be covered further in Section 5.2.2.3. Then, the prototype is planned to be further developed to match these requirements over the course of two weeks, Section 5.2.2.4 will cover this. After the sprint is done, an evaluation is planned to be done on the prototype, this is discussed in Section 5.2.2.5. After the evaluation is done a new sprint will begin.

A rough plan of what could be implemented in these sprint is shown in the following list:

- During the first sprint, basic vehicle physics are planned to be implemented so that the player is able to control a vehicle and drive around a basic track.

- The plan of the second sprint is to implement the dynamic difficulty to match the challenge with players skills.

- The final sprint is planned to focus on adding further game mechanics to make the experience more exciting and engaging.

5.2.2.3 Changing requirements

This activity is planned to be done in weeks twelve and fifteen, after each evaluation has been completed. The purpose of this activity is to react to user feedback from the previous evaluation phase, and assess what progress has been made by possibly changing requirements and looking for new design solutions that can be implemented in the next Sprint. Essentially, this activity is planned to be much similar to the methodologies described in Sections 4.2, 4.6.1, 4.6.2 and 4.6.3.

5.2.2.4 Prototyping

The prototyping phase is where the implementation of the design solution is planned to take place. This is the most time consuming task of the study which is why it has the most weeks dedicated to it in the schedule. The implementation is planned to be done in the author's preferred game engine: Unity [47]. Some assets, including vehicle model and environment may be supplied by Lynk&Co or Chalmers.

5.2.2.5 Evaluating

A total of three evaluations are planned to take place. The first evaluation is planned to be done after the first two week prototype phase in week twelve. This evaluation is planned to focus on testing features regarding the mechanics of the vehicle. For example, how difficult it is to control the vehicle, and how realistic it feels to drive. The second evaluation, taking place in week fifteen, is planned to examine the implemented dynamic difficulty to see if it is producing the desired results. The last evaluation is planned to take place at the end of the implementation, this evaluation is planned to be done at a larger scale to see how well the prototype works at giving the participant the feeling of immersion. The evaluation is planned to be done by first letting the participants get hands-on experience with the prototype while being observed (4.4.3) by the researcher. Afterwards, the participants are planned to be asked to fill in the immersion questionnaire created by Jennett [1], see Section (4.4.3) regarding information about questionnaires. Additionally, a short interview (4.4.1) is planned to be held to get further information and insights about the participant's experience. Note that these mentioned evaluations are planned and thus are subject to change.

5.2.2.6 Finalisation

During the last four weeks, the study is planned to be concluded by summarising the most important findings in a report. Also, a comprehensive set of guidelines are planned to be created to aid future researchers and game designers regarding the feeling of immersion for a variety of experience levels. Furthermore during this time,

work is planned to be done towards the creation of a presentation of the study, and time is planned to be spent on being an opponent of another Master Thesis project.
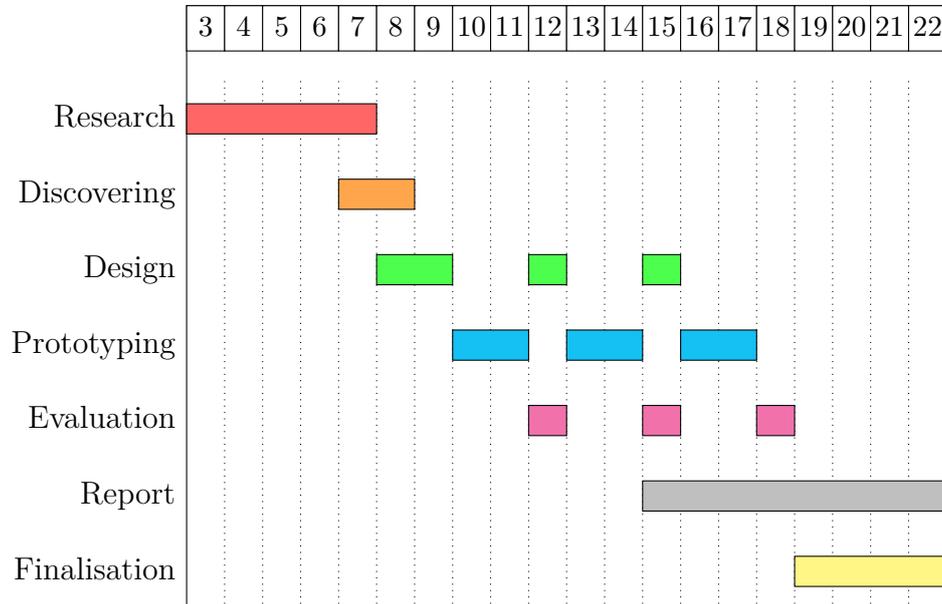
Figure 5.2: Gantt chart for the planned schedule

5.3 Phase 1

As stated in Section 5.2.2.2 the goal of the first sprint was to make a basic vehicle which the player is able to control as they drive around a track. A first sprint planning phase was done as described in Section 4.6.1. It was determined that the product would increase in value by adding the ability for the user to control the vehicle. This is important because we want the user to be able to feel that they have control of the vehicle, and are not watching, for example, a video of someone else driving a vehicle. The way this goal would be achieved was by implementing common characteristics for the vehicle such as acceleration, steering, and friction. Furthermore, basic collision with the ground is also planned to be implemented.

5.3.1 Design

During the design phase, experience goals, a persona, and a scenario were created. The experience goals were created to better detail what we want the player to feel when playing. After the experience goals were created, they were then prioritised based on importance. For each experience goal, some general ideas were written down on how these goals could be achieved. The results of this process can be seen in Figure 5.3. The experience goals will now be described in more detail, and will be mentioned in order of importance.

25

Figure 5.3: Player Experience goals created at the start of the project

Getting consumed by the virtual environment. This experience goal was chosen to represent the fact that the experience should be immersive. As described in Section 3.1, immersion has the following features: lack of awareness of time; loss of awareness of the real world; involvement and a sense of being in the task environment. Getting consumed by the virtual environment summarises these features of immersion in a good way and makes it clear that the experience should be immersive. As seen from Figure 5.3, this could for example be done through the addition of realistic visuals, other elements not related to the race could also help with immersion as the player could have several things to look at. The addition of audio could further enhance the realness.

Challenging but fun and engaging. Making the experience challenging while not making it too difficult for the player follows the theory of Flow described in Section 3.2. Dynamic Difficulty Adjustment described in Section 3.5 will help with creating the right challenge for the player. This could also be done through the addition of different game elements such as power-ups or speed boosts. One could also have novelty in the track design such as having loops or having the ability to drive on walls.

The player is their own enemy. As described in Section 1.2, one of the main limitations of this study is that it will only be a single player experience. It was thus chosen to add this experience goal in order to give the player an additional challenge. One could accomplish this through different challenge aspects such as lap timers or a ghost replay. The player could also leave behind different obstacles so they have to think carefully about how they drive around the track.

Driving is easy, but getting the extra score will be hard. This experience goal expands further on the previously mentioned goal. By making sure the controls are kept easy, the experience will remain accessible for players with very little experience with racing games. Experienced players will enjoy the challenge of getting the extra score to keep engagement levels high. This could for example be implemented by having dynamic difficulty adjustment, it could also be done through the addition of different kind of objectives such as completing a lap in a certain amount of time.

Feeling of ownership. One of Lynk&Co's goals and values is to give the player a feeling of ownership. Furthermore, Schmierbach et al [48] found that 'allowing players to customise their car increased identification, which amplified both transportation and presence'[48, p.367]. It was thus decided to add this experience goal to further investigate this area. This could for example be implemented through the ability for players to customise their vehicle by letting them choose the model and colour.

After the experience goals and general ideas on how to achieve them were created, they were further expanded by brainstorming specific game mechanics and elements. These would be of much help by giving concrete examples on how to implement the experience goals in the prototype. The result of this process being done on the experience goal 'Getting consumed by the virtual environment' can be seen in Figure 5.4.

To further define the design space, a persona and scenario were created. The goal of the persona was to provide a concrete example of the background and lifestyle of a potential user who would play the experience. The goal of the scenario was to create a future hypothetical situation which illustrated how the experience might be played by the described persona. Both the persona and scenario can be found in Appendix A.

5.3.2   Prototyping

The physics of the vehicle were created using Unity's built in Wheel Collider component [49]. Taken from Unity's own description of this component: 'The Wheel Collider is a special collider for grounded vehicles. It has built-in collision detection, wheel physics, and a slip-based tyre friction model' [49]. It was thus relatively straightforward to implement the physics of the vehicle. More time was spent on tweaking the values of the Wheel Collider component in each wheel to make the vehicle behave in a natural way. This included things such as how easy it is for the

Getting consumed by the virtual environment	Space	Track light	Crowd lights	Hologram	AR type stuff	Crowd cheering	Tire noise	Engine
	Race track	Wireframe lights	Glitch effects	TV ads	Screens	Music	Environment noise	Rain
	Nature	Strobe Light	Spot light	Lazer	Neon lights	Start sound	Switching gears	Sound effects
	City	Overhangs	Skyscrapers	Crowd	Montains	stars	planets	Flying donuts
		Billboard	Cones on track	Bariers	flags	Airplanes	Clowds	Zeppelins

Legend: Environment, Lights, Objects close to track, Sounds, Objects farther away

Figure 5.4: Examples of game elements that can be included in the prototype to achieve the experience goal 'Getting consumed by the virtual environment'

vehicle to loose grip, how fast it could go, and how easy it should be to turn. To make the vehicle more interesting to control, a feature was added to allow the player to carry out a manual drift. This was done by making the back tyres lose grip when the player quickly taps the brake while the vehicle is in motion.

The vehicle was constructed by creating one large rectangle, resembling the body of the vehicle, with four identical cylinders attached to it, resembling the wheels. The body was given a red texture while the wheels were given a wooden texture. The results can be seen in Figure 5.5.

A basic track was created in the 3D modelling program Blender [46]. The track was made short with some difficult turns and some easy turns to make it interesting to drive on. It was also decided to make the track float in the sky so that if the player went off the track they would fall. This made it more important to stay on the track, increasing the challenge of it. The first iteration of the track can be seen in Figure 5.6.
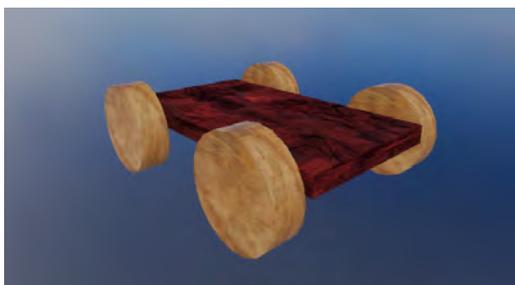
Figure 5.5: The first iteration of the vehicle the player controlled

Figure 5.6: The first iteration of the track the player had to drive around

Two different camera modes were implemented. One where the camera was in a third-person position with the whole vehicle in view, and another where it was in a first-person position where the player would be on top of the vehicle with only the front wheels in view. The player could choose to switch between the two camera modes at any time while playing and the camera would smoothly transition between the different views. Both cameras had a slight smoothing effect to make it look natural when driving around the track.

The next step was to register if the player had gone a lap around the track. This was done by implementing a checkpoint tracker. This made it possible to check if the player was driving in the right direction, a lap would only count if the player had successfully gone through all the checkpoints in the right order. These checkpoints were also used for respawn points; when the player fell off the track, they would respawn at their last reached checkpoint. A timer was also created which kept track of the player's fastest lap. This was done to add an additional challenge by incentivising the player to beat their personal best time. User interface elements were created to show the player's current and personal best lap time. Further interface elements were also created for debugging reasons; information such as the vehicles speed, tyre grip, and tyre RPM could all be displayed on screen and monitored.

Further improvements were made to both the vehicle and the environment. The vehicle model was made more realistic by updating it to a Go Kart model taken from a royalty free source [50][1]. This model can be seen in Figure 5.7. The environment was made more interesting by adding simple shapes around the track. The purpose of these objects were to provide the player with more things to look at while driving around the track. This track can be seen in Figure 5.8.

Figure 5.7: The second iteration of the vehicle the player controlled

Figure 5.8: The second iteration of the track the player had to drive around

As the experience was planned to be in VR, the development of making the experience work in VR also started in this phase. The VR headset which was used was the HTC Vive Pro 2 which was provided by Chalmers. The Unity XR interaction toolkit [51] was used as it provides an easy way to make various VR interactions work within Unity. It was planned that the player would have to grab on the steering wheel and rotate it in order to steer, just as a steering wheel works in real life.

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[1]Model created by Spaehling, model is under the following license: https://creativecommons.org/licenses/by-nc-nd/4.0/

5.3.3 Result

The outcome of the sprint was the creation of a sophisticated vehicle controller which lets the player control the vehicle in a realistic way. The player can drive around a simple track and a timer will keep track of the time it takes for the player to drive around. Due to the VR equipment being supplied late, it was unfortunately not possible to make the steering work with the VR controllers at the end of the sprint.

It was planned that the priority for the next sprint would be to add a way for the user to interact with the steering wheel in VR, also, further mechanics would be added to make the track more interesting and engaging to drive on.

5.3.4 Evaluation

Before doing the evaluation, the IMPACT method described in Section 4.4 was done. This resulted in the following outcome:

Intention: Get an alternative view on the product from university students. How to move forward, what to think about when considering the research question.

Metrics: Observe the difficulty of the track, how focused they are on the task. Then some open ended questions will be asked about their experience.

People: University students.

Activities: Firstly, have a quick introduction to the project and prototype. Then, let the participants play. Lastly, ask open ended questions about their experience.

Context: No outside variables will be considered.

Technology: The experience will be played on a laptop. The participants will use a wireless Xbox One controller to control the vehicle.

A total of three participants were part of the evaluation. Overall, the students were satisfied and impressed with the prototype. However, they did have some points of improvements and feedback, these will be mentioned now.

- Vehicle handling can be made more predictable and realistic.

- Show more feedback on how well and fast you are driving and progressing.

- Find a better way to motivate the player.

- Just driving laps gets boring after a while. Keep the player more engaged by making more things happen, this can, for example, be done by having the following elements: real time events, secondary objectives, coins, speed boosts, jumps to make it more exciting, obstacles on the track that could be dynamic or static, changes in environment when driving around the track.

- Additions of sounds can make the experience more immersive to play.

The biggest issue with the prototype was that it was not engaging enough. The participants stated that the base functionalities were good but there needed to be more things to do while driving around.

5.4 Phase 2

A slight pivot of the project was done during the start of this phase. It was decided that there were going to be no efforts in trying to examine the effect of dynamic difficulty on immersion as a better method of going forward was found. Instead, efforts were going to be put into creating three different types of experiences. These three experiences would make the end evaluation more sophisticated as the user would get a better idea of what type of experience gives them more immersion. This approach seemed to be more appropriate in answering the research question. It was planned that the experiences would focus on creating different types of immersion, this includes immersion through realism, through engagement, and through "craziness".

For each of the three experiences, features will have to be implemented in order to make each experience unique and distinguishable from the others. As a start, the main focus will be to add these distinguishable features for each experience, then, further improvements will be made by adding environments and audio.

5.4.1 Design

Both the way the different environments were going to look and how the player would interact with the vehicle had to be designed before starting the sprint. The different aims for the environments are taken up in Section 5.4.1.1, while the different steering wheel interactions will be taken up in Section 5.4.1.2.

5.4.1.1 Environments

It was planned that the three experiences would each be set in a different environment. This was decided to further make them easily distinguishable from another, while also investigating if changes in environment would effect immersion. The environments were chosen to be a forest, a city, and a space setting. These environments would immerse the player through realism, engagement, and "craziness" respectively. We will now go though how the design of each track was planned.

Starting with the Forest track, the aim was to make the player feel immersed through realism, meaning that the player is immersed through the realism of the vehicle controls and the environment around them. Sounds and other real life effects such as shadows and realistic lighting thus had to be prioritised for this track. It was decided not to include any game elements in this track and to keep actions per minute low. This was because the aim of the track was solely to let the player enjoy the environment around them and not to become focused on other game objectives such as driving fast or gaining a certain amount of points.

The City track would immerse the player through engagement. The way the track would be made engaging would be through a mix of game elements. Different kinds of game elements were considered, however, most of these got discarded as they would require too much time to implement into the prototype. The elements which were planned to be implemented were: a timer, a ghost player which would mimic the player's best performed lap, and the ability to collect pickups which would allow the player to boost their speed. These elements all seemed to be appropriate to implement as they would add basic game elements which would engage the player.

Finally, the aim of the Space track was to give the player immersion through "craziness", meaning that the player would get immersed through a high amount of visuals happening around them, while also including various game elements to keep the player engaged. The visuals were planned to be various asteroids and planets which would be seen around the track. While the game elements would be similar to that of the City track. It was planned to have a less realistic vehicle behaviour for this track. The vehicle was planned to be able to drive on any surface, no matter its orientation. The track would be designed in a way where it would twist and turn in 3D space and the vehicle would still just drive on the track normally. This would further increase the craziness of the track as it would be similar to going on a rollercoaster ride.

5.4.1.2 Interaction

Three different types of methods and hardware for using the steering wheel were considered. The first option was to use a racing wheel controller, these controllers are often used by realistic racing game enthusiasts and offer the best control and feedback.

The second option was to use the HTC Vive VR controllers themselves, this was a valid option with two main ways to control the steering wheel. First, one could have to "grab" on to the steering wheel with the controllers by pressing down the grip button on the VR controller. While grabbing the steering wheel, one would then have to move the controllers in a circular motion in order to rotate the steering wheel, just like a real steering wheel works. The second way would be that the steering wheel was always being grabbed without the player having to press the grip button. They would then have to move the two VR controllers around to simulate the steering.

The third and final option would be to continue using the Xbox controller as the input to control just as it worked in the first phase.

The steering wheel controller would have been used if there was one available for the study as it seemed the most realistic and intuitive option to steer. Unfortunately it was not possible to gain access to one for the study. The option that was chosen was where the player would have to grab the steering wheel by pressing down the grip button on the VR controllers. This option was chosen because it seemed to be the most realistic and intuitive way to interact with the steering wheel that was available. Just as in real life, one has to grab onto the steering wheel in order to

steer it. By using this option it would also be possible to steer with only one's right or left hand, or to steer with both hands.

5.4.2 Prototyping

When starting the prototyping phase, priority was given to the elements which could be reused for several environments. For example, engine and skidding sounds could be used on all three environments, so it was given high priority . The ability to collect coins was planned to be done on two tracks, so that feature was also prioritised.

5.4.2.1 Choosing of environments

To save time, different environments to fit the Forest, City, and Space tracks were searched for on the Unity Asset Store [52]. This is a website where one can find various 3D and 2D models, textures, and programming tools specifically tailored for use in Unity projects. In general, all the environments that were chosen were of high quality in terms of graphics. Details about each selected asset will be gone through now.

The forest environment[2] had a built in racing track. This track fit well as it had no sharp turns, making it easy for inexperienced players to drive on. The track includes some minor changes in environment, as at one point, the track goes into a mountain through a tunnel. This incorporates some of the feedback given in the first feedback session discussed in Section 5.3.4. The environment around the track was also realistic with trees and rocks closer to the track and mountains further in the background creating an illusion of depth and thus making it almost identical to real life.

The city environment[3] was chosen to be set in a futuristic scene. This would make the environment become more abstract and thus make the planned game elements fit in with the environment more. The asset contained many different models such as neon signs, robots, houses, and many other props. As there was no premade track design or environment, it was planned to create a completely custom track and populate the environment around it with the models available in the asset.

The asset used for the space environment included different types of asteroid models[4]. Each asteroid could have a glowing effect where colour and intensity could be easily adjusted. Each asteroid could also be split into smaller asteroid pieces. It was planned that this would be used when an asteroid got hit by the player or crashed onto the track.

Before these assets could be implemented into Unity, a request to Chalmers was sent to let them carry out the purchase of the assets. While waiting for the transaction to be carried out, several other implementations were done which will be taken up in detail now.

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[2]https://assetstore.unity.com/packages/3d/environments/forest-racing-track-117020

[3]https://assetstore.unity.com/packages/3d/environments/sci-fi/cyberpunk-cyber-city-120137

[4]https://assetstore.unity.com/packages/3d/environments/sci-fi/highres-asteroids-pack-72323

5.4.2.2 Vehicle sounds

Various different sounds were added to the experience to make it more realistic and enjoyable to play. Firstly, engine sounds were created by making a dent in a metal can at its centre point and humming into the opening. The sound created by this was recorded and edited in the audio editing software Audacity [53]. A script was then created in Unity which changed the pitch of the sound to simulate that the engine was changing gears. Note that the player did not have the ability to change gears by themselves, this was decided not to be included as it would be too complex for inexperienced players. A skidding sound was also added as it further increased realism and also gave audio feedback to the player when the vehicle lost grip in any of the tyres. The skidding sound was implemented by downloading a royalty free skidding sound from a YouTube video and importing it into Unity. A script was created which faded the sound in and out depending on the *sidewaysSlip* value stored in each WheelCollider component of the vehicle.

5.4.2.3 Increasing Engagement

Further engagement elements were added including a ghost player and an improved track. These two elements will be introduced now.

A ghost player was added to create an extra engagement aspect to the experience. This was done by recording the player's position and orientation during a lap. If the player finished the lap and set a new record in doing so, the recording will be saved and played back. This would allow the player to see how they drove on their best performed lap and compete against themselves. The ghost model was made as a transparent version of the player vehicle model and can be seen in Figure 5.9.

A new, improved, and more engaging track was created in Blender which allowed the player to perform a jump over a previous section of the track. White road markings were also added to the track so that the player can better tell how fast they are going. This decision was also inspired by the feedback from the first evaluation session (5.3.4). The track can be seen in Figure 5.10.
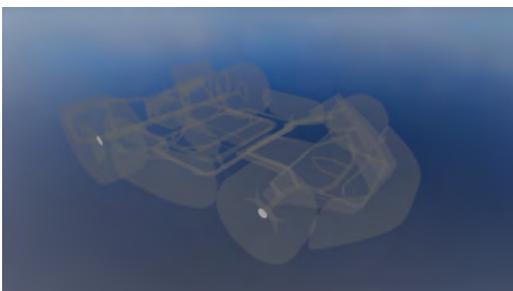
Figure 5.9: The ghost player model

Figure 5.10: A more exciting track was created which included a jump

5.4.2.4 VR Development

The VR development continued throughout the duration of this sprint. Several features had to be added and changed to make the experience playable in VR.

These features will be discussed now.

To make the experience as realistic as possible, instead of the camera being at a fixed orientation in either first-person or third-person view, the camera would always need to be in first-person view to make it identical to real life. The player could then move their head around with the Head Mounted Display (HMD) and the camera would orient itself identically to it. As is common with VR games, virtual hand models were added which represent the position of the VR controllers. Both the change in camera and the addition of player hands could easily be added with the help of the Unity XR interaction toolkit [51].

Figure 5.11: A diegetic timer seen at the side of the track

Making the player be able to use the VR controllers to steer the vehicle was more difficult to get working than anticipated, they were however successfully implemented after a lot of effort. When the VR controller now got close to the steering wheel and the player pressed the grip button the virtual hand would grab the steering wheel. This would be visually shown by playing an animation where the hand would go from an open hand to a closed hand around the steering wheel. While the player was holding the steering wheel, they could move their hands in a circular motion around the pivot of the steering wheel. This would then steer the vehicle accordingly. When the player released the grip button, the virtual hand would release the steering wheel and go back to its original state.

Another features that was changed was the way the timer was shown. Previously, one could always see current lap time and best lap time, however, due to the change of the camera to VR, this was no longer the best option. The timer was instead chosen to be of diegetic form, a common attribute of UI elements seen in other VR games. The effect of diegetic UI in VR has also been studied by Salomoni *et al.* [54]. They found that 'the use of a diegetic interface has a significant (and not accidental) effect on the perception of immersion' [54, p.182]. Diegetic timers were thus added

along the side of the track for the player to see. Three timers were added in total at certain checkpoints. Each timer showed the current lap time and a split time which showed the best time between the start of the lap to that checkpoint. The checkpoint system was also improved to support these lap splits. The new diegetic timers can be seen in Figure 5.11.

5.4.2.5 Creation of Environments

As mentioned in Section 5.4.2.1, three different environment assets were requested to be purchased by Chalmers. When these assets were acquired, the environments could be put into the Unity project and made into beautiful playable tracks.

As the forest asset already had a pre-made track and a suitable environment, no big changes had to be made to it. The vehicle model and its relevant behaviour scripts could be easily moved to the Forest track to make it possible to drive around it. When testing the driving with the existing vehicle behaviour from phase one, it seemed that the vehicle drove in an unrealistic way. It was going too fast and responded too sharply to player inputs. This was now only realised because the environment was scaled correctly to the size of the vehicle model. Slight changes were thus made to the vehicle physics to match it more with how cars behave in reality. A reverb audio effect was also added when the player went through the tunnel to make the vehicle sounds more realistic while the player was in the tunnel. This could easily be done through Unity's Reverb Zones script [55]. An example of how the environment looked like at this stage can be seen in Figure 5.12
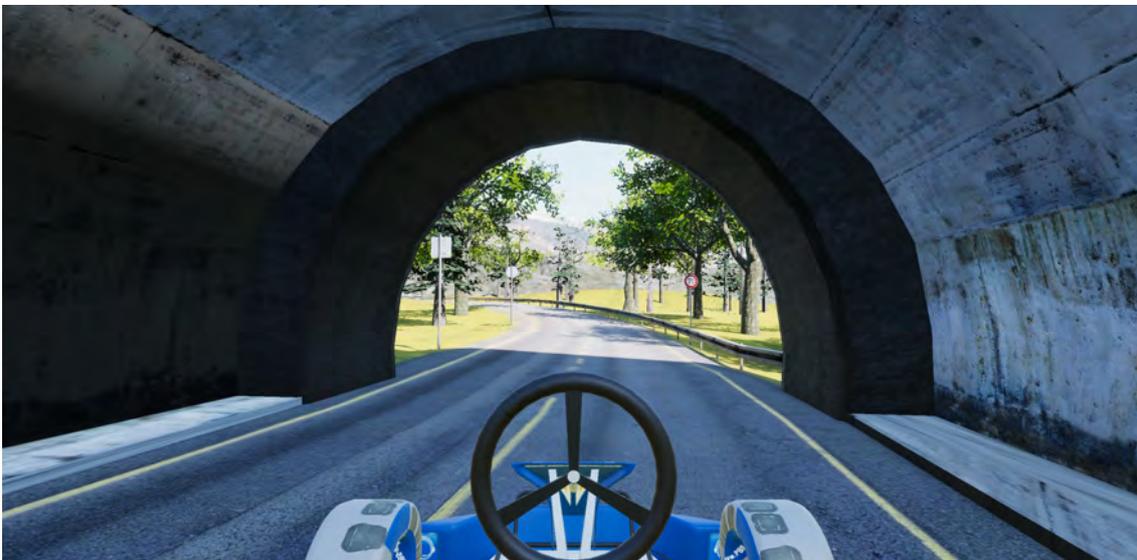
Figure 5.12: The player driving out of a tunnel in the Forest track

The city environment was created by first designing a track and then adding various different buildings and props around it. The track was designed to have a mixture of long and short sections to make it more enjoyable for experienced players, following what has been found by Surarerks and Kotrajaras [56], and Galdieri *et al.* [57]. To make the track more interesting to drive around, different shortcuts were made

so that players would get rewarded for their curiosity. After the track had been designed, various different buildings provided by the city asset were placed next to the track. When this was done, further props such as street lamps, cables, neon signs, and food stands were added to make the environment more interesting. Taller buildings were also placed further away from the track to make the player feel like they were driving in a vast city. The results of a finished street can be seen in Figure 5.13.

Figure 5.13: One of the many views one can see when driving around the City track

Coin and speed boost game elements were also implemented on the City track. These two elements seemed to be a simple way to increase the amount of features the player could interact with and act on. The coins would spawn slightly to the side of the track, the reason for this was so that the player would have to make an extra effort if they wanted to pick up the coins. A speed boost feature was also implemented which allowed the player to go faster for a short period of time. The coins acted as fuel for the boost, each time the player picked up a coin it would play a coin pickup sound and it would then increase the boost fuel. The player could decide whether to boost at any time; with the press of a button on the VR controller, the boost meter would get used and the vehicle would go faster.

Because the aim of the City track was to motivate the player to complete a lap as fast as possible, further elements were added to support this. One of these elements was a countdown timer. Before the player would start racing, there would be a countdown to give the player a feeling they were in a race. A diegetic visual of a countdown timer was added hanging over the track. Music was also added to create an extra element of excitement. Lastly, the previously created diegetic timer elements were transferred to the track.

Finally, the development of the Space track was started. Several different track

(a) The first iteration of the Space track. It is shaped like a Möbius strip and has sharp turns
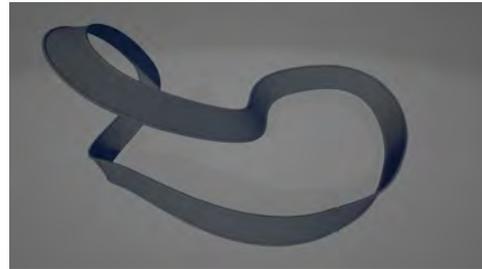
(b) The second iteration of the Space track. It is a simplified version of the first iteration
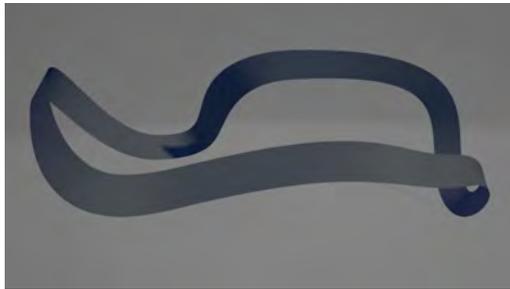
(c) The third iteration of the Space track. It has a handful of turns and twists

Figure 5.14: Three iterations of Space tracks

iterations were designed, these tracks can be seen in Figure 5.14. Starting with the first iteration of the track which can be seen in Figure 5.14a, this track is shaped like a Möbius strip. This meant that the player would first drive on one side of the track and then drive on the other side. This track was simplified and turns were made less sharp, to make the track easier to drive on. This resulted in the second iteration of the track seen in Figure 5.14b. After some internal testing, having the idea of the track shaped like a Möbius strip was discarded. This was because driving on the other side of the track was not particularly interesting as one could not see the rest of the track. A different design was thus created which resulted in the third iteration of the Space track seen in Figure 5.14c.

A new vehicle behaviour had to be created to make the vehicle drive on any surface. The way this was implemented was by creating a sphere collider which would roll along the track, different forces would then be applied to this sphere to make the vehicle move. The model of the vehicle was set to follow the sphere and be oriented on the normal of the surface it was driving on. Gravity would also act on the sphere according to the normal of the surface to prevent the vehicle from flying off the track. Unfortunately, the full implementation of the vehicle behaviour could not be completed before the end of the sprint and could thus not be tested in the evaluation.

5.4.3 Result

The sprint was semi-successful, the forest and City track worked successfully in VR, but due to some delays and difficulties, the Space track could not be finished on time.

A Forest track was created which is set in a large nature style environment where the player drives around and through a part of a mountain. A City track was also created, it is set in a futuristic city environment. The player has the goal to drive around the track as fast as possible, they have the ability to boost their vehicle, but only if they have picked up enough coins to fuel their boost.

Both of these tracks work in VR and the player uses the VR controller to grab on to the steering wheel in VR and rotate it like one would with a real steering wheel.

5.4.4 Evaluation

Before doing the evaluation, the IMPACT method described in Section 4.4 was done. This resulted in the following outcome:

Intention: Get usability and general feedback from university students. How to move forward, what to think about when considering the research question.

Metrics: Observe the difficulty of the controls. Then some open ended questions will be asked about their experience.

People: University students.

Activities: Firstly have a quick introduction to the project and prototype. Then,

let the participants play. Lastly ask open ended questions about their experience.

Context: No outside variables will be considered.

Technology: The experience will be played on a desktop computer. The participants will use a HTC Vive Pro 2 with its Vive controllers.

A total of four participants were part of the evaluation and gave valuable suggestions of features to add or change. Three participants felt the need to stop playing because of cybersickness. Participants also had difficulty interacting with the steering wheel in VR. More details about the evaluation will be taken up now.

One participant said that the Forest track should have more landmarks and become more lively. They said that it was hard to see where they were positioned on the track while driving, as the surroundings around the track looked very similar. The participant also said that the goal of the Forest track was unclear and that there should be at least be some goal so that players know what to do. They did however state that they liked the Forest track more compared to the City track. In contrast to the first participant, another said this was because the Forest track made them more relaxed due to the little amount of challenge or game objectives, which in turn made them feel more immersed. The participant also said that the coins giving boost fuel did not make much sense, their first thought when seeing coins was that they would give points and not fuel.

The biggest problem with the two tested tracks was the way the participants had to control the vehicle. This was especially true with participants inexperienced with VR games, but experienced players were also having trouble controlling the vehicle through the VR interaction. Participants did not like that they had to keep pressing down the grip buttons on the VR controller in order to grab the steering wheel. Even after only a few minutes of playing, two participants said that it was hurting their hands to constantly have to press down the grip button. Some participants stated that the vehicle was too responsive when steering and it therefore felt less realistic compared to a real vehicle. One participant also said he didn't feel in control of the vehicle, adding that the vehicle unexpectedly went off the track without them knowing why it happened. This participant also said that they had to constantly think about how to make the vehicle behave as they wanted.

Participants also had extreme problems with cybersickness, this is possibly because of the vast amount of motion the participant is experiencing while playing. One participant said that when the vehicle went on a slope, they thought that they also should be moving the same way which caused them to feel dizzy.

5.5   Phase 3

This phase will act on the feedback given in the evaluation session in phase 2 described in Section 5.4.4. This will be done by making some minor changes to the

Forest track, by making interaction better, and by decreasing cybersickness. Improving vehicle controls and behaviour will allow the players not to get frustrated when playing. Users will also have a chance to get immersed by avoiding having to stop playing because of cybersickness. The development of the Space track will also be continued.

5.5.1 Design

A difficult choice had to be made when choosing whether to improve the VR steering interaction, or to discard the implementations made and instead go back to the Xbox controller. It was chosen to make the vehicle be controlled with an Xbox controller, just like how it worked in phase 1, instead of adjusting the VR controls to make them more easy to use for the player. This was to minimise the risks that the VR steering interaction would still be difficult to control after constant development. The development time could instead be used for other meaningful implementations.

Cybersickness was going to be reduced by minimising roll and pitch rotations of the vehicle, to decrease the amount of motion the player sees while turning and braking the vehicle.

The Space track was still incomplete, but it was planned that the asteroids would be used as game elements. The player would be able to shoot the asteroids to get points and the goal of the track would be to get as many points as possible. The way the player would shoot was with a laser, which could be aimed by the way the player looked with their head. If an asteroid would get hit by a laser, it would break into smaller pieces, if a smaller piece would get shot it would explode and disappear. To incentivise the player to drive around the track while shooting the asteroids, coins were decided to be added to the track which the player could pickup. These coins would give the player additional points. To further increase the amount of craziness, it was decided that some asteroids would crash into the track and break apart in front of the player.

Several new assets were searched for on the Unity Asset Store [52]. These were all medieval style buildings which were planned to be placed on the Forest track. This was done in response to the feedback gotten from the previous evaluation session taken up in Section 5.4.4. Having several distinct buildings placed around the map would increase the amount of landmarks, thus making it easier for the player to know where they are on the track, and also having more interesting things to look at.

5.5.2 Prototyping

Some changes were made to the amount of motion the player would experience when driving the vehicle, this may decrease the chances of the player feeling cybersickness. This was done by changing the damping rates in the spring of the vehicle. Previously, when the player would turn, brake, or accelerate, the springs of the tyres would contract at a fast rate and the whole body of the vehicle would tilt, making a motion

that would roll or pitch the camera a few degrees at a fast speed. To decrease this motion, the contracting rate was made slower which greatly decreased both roll and pitch movements the player would experience. This alteration did not change the behaviour of the vehicle to a noticeable extent.

Some slight changes were made to the Forest track. More distinct objects such as houses and bigger buildings were placed around the track. One big castle was also placed on top of the mountain the player is driving around, this castle can be seen in Figure 5.15. More additions to the environment around the City track were also added to make it more lively. This was done by adding robots to it which would move and fly around the track. The coins were changed into gas canisters to make their purpose more clear to the player and the pickup sound was also changed to resemble a gas canister more. An image of the robots and gas canister can be seen in Figure 5.16 . A boost sound was also added to make it clearer to the player that they were boosting.

Figure 5.15: A castle was put on the mountain on the Forest track
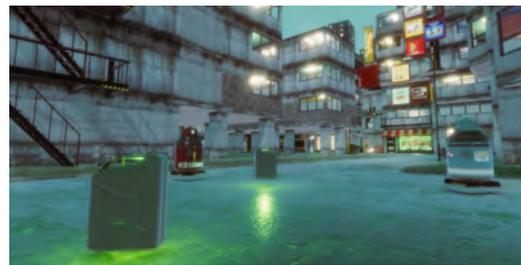
Figure 5.16: Robots were added to the City track, and the coins were changed to gas canisters

The vehicle behaviour in the Space track was developed to be fully working as it was planned to be. It could now drive on any surface no matter its orientation. After some internal testing of the track made in the previous phase, it was decided that it was too difficult to drive on as one could easily fall off the track. It was thus further simplified by making the turns less sharp and adding borders around the edges of the track which prevented the player from falling off. Road markings were also added to the track so that the player can better tell how fast they are going. The track was also made transparent, to make it easier for the player to see their surroundings. This resulted in the final iteration of the track which can be seen in Figure 5.17.

The asteroid and coin game elements were added to the Space track. An explosion function was written which applied a force to each of the smaller asteroid pieces, this gave the impression of the asteroid breaking into smaller pieces. Another implementation was made which made an asteroid fall towards the track. This was implemented in such as it would fall just ahead of where the player was driving so that the player would have a chance to see the asteroid falling on the track. The laser ability was also implemented. This fired a fast shooting laser projectile in the

Figure 5.17: The final iteration of the Space track. It has boarders around the edges to prevent the player from falling off. Different asteroids and planets are positioned around the track.

direction the player camera was pointing at. If the laser collided with an asteroid, it would either break it up into further pieces, or destroy it and cause an explosion. To make destroying asteroids more exciting, explosion sounds and particles were added as well as laser shooting sounds.

Coins were implemented by being spawned on set positions around the track each lap. A scoring system was also added where the player would increase their score by both hitting asteroids with their laser and by collecting coins. The player would get five points when hitting an asteroid and two points for collecting a coin. These points would be displayed below the steering wheel of the vehicle diegetically. An example of how the Space track looks like while playing can be seen in Figure 5.18

5.5.3 Result

The sprint was successful, the planned activities were all done in the given time frame. The way the player controlled the vehicle was reverted back to the Xbox controller and changes were made to the vehicle behaviour to reduce the amount of motion the player is experiencing while driving. As for the tracks, slight additions were made to both the forest and City tracks whilst more substantial changes were made to the Space track. The Forest track had various different buildings added to it. The City track was made more lively by the addition of moving robots, coins were also changed to gas canisters and a boost sound effect was added. A Space track was implemented which explores the 3D space by twisting and turning in various ways. The track is set in outer space with planets, stars, and asteroids around it. The player can shoot asteroids which will give them points. Asteroids can explode into smaller asteroids and crash onto the track. Additional points can be gained through the collection of coins spawned on the track.

Figure 5.18: Asteroids, planets, coins, and explosions can be seen around the player in the Space track.

5.5.4   Evaluation

Before doing the evaluation, the IMPACT method described in Section 4.4 was done. This resulted in the following outcome:

Intention: Get valuable qualitative information from a variety of people about their experience with the different tracks.

Metrics: Open ended questions will be asked about different aspects of the experience. A deep understanding of the topics discussed will be aimed for.

People: University students, industry experts, friends, and family will take part of the evaluation. Around 10 people are planned to be part of the evaluation.

Activities: Firstly, a quick introduction to the study will be explained. The participants consent will also be asked for. The consent form can be seen in Appendix B. After the participant has given their consent, they will get an introduction to the controls of the experience and how the VR headset works. The participant will then play each track in the following order for at least two minutes: Forest track, City track, Space track. After they have played each track, questions will be asked about their view on their experience. These questions can be seen in Appendix C.

Context: No outside variables will be considered.

Technology: The experience will be played on a desktop computer. The participants will use a HTC Vive Pro 2 VR headset with an Xbox One controller.

It was originally planned that the participants in the final evaluation would be asked to fill out the immersion questionnaire created by Jennett *et al.* [1]. However, this

questionnaire was decided not to be done because this kind of feedback was deemed to be inappropriate for the final evaluation. It was not important to understand to what extent they got immersed in a given experience, it was instead important to understand why participants felt immersed.

A total of 14 people participated in the evaluation. Many comments and observations were made, these will be taken up in detail now.

It was found from the evaluations that cybersickness was much a subjective factor. Some participants had no problems with cybersickness at all, while - in extreme cases - some had to stop after only a few seconds of playing. The majority of participants in the evaluations had problems with cybersickness to a moderate extent and this was mostly the case with the Space track. Participants explained that the sickness was holding them back from playing in a normal way. They were actively trying to avoid cybersickness by driving and turning slower to decrease the amount of motion they were experiencing.

Participants also stated that the audio helped them feel immersed in the environment. They said that sound effects, music, and spacial audio all contributed to the feeling of immersion. Most of the participants took note of the change in engine sound when going through the tunnel on the Forest track. Interestingly, one participant even thought environment sounds such as birds and wind were playing on the Forest track while, in fact, none of those sounds were actually playing.

Some of the more experienced players stated that they where not satisfied with the realism of the controls on the Forest and City track. They said that the turning felt too direct and sharp, and as a result lowered their enjoyment of driving the vehicle. Some participants also stated that they did not like the space controls as they felt the vehicle was very slippery as if they were driving on ice. This however also could have been because they were not paying much attention to driving the vehicle as they were focused on shooting the asteroids.

It was also found that when, according to the player, the vehicle behaved unexpectedly they got confused and frustrated. Two participants also said that the boost meter in the City track was hard to see as you had to look below your steering wheel to see it. One participant stated that they where not paying attention to how much score they had as they were too focused on shooting asteroids.

Many of the experienced players stated that they liked the City track the most because of its difficulty. Furthermore, experienced players said that the shortcuts in the City track increased the engagement of the track. Regarding the Space track, one inexperienced player said that they liked having a wide track that prevented them from falling off, while a more experienced player stated that they did not like that aspect of the track and wanted a bigger challenge instead.

Many participants said they preferred tracks with game elements. They found driving around the Forest track very boring after driving just one lap, however, some participants said they preferred the nature environment and said that the game

elements should be added to the Forest track. Two participant stated that they preferred to play a more relaxing style, however, they would prefer to have more elements added which supported them to do so such as having a radio function or smaller objectives.

6

Final Results

This chapter includes the final results of the project. First, in Section 6.1 the three prototypes that were created will be described in detail. Then, in Section 6.2, eight comprehensible sets of guidelines will be detailed.

6.1 Prototypes

In this section, details about what was included in the final three track prototypes which were created during the project will be described. In each section, a short description about the general feel of each prototype will be taken up, then, a more detailed description of what is included will be given.

Figure 6.1: The Forest track lets the player sit back and enjoy their surroundings

6.1.1 Forest Track

The Forest track is set in a large nature style environment where the track goes through and around a part of a mountain. Different medieval style buildings can be seen around the track and there is one large castle located at the top of the mountain. The player has the ability to use a VR headset and an Xbox controller to control a realistic vehicle. They are placed at a fixed point within the vehicle,

the player can look and drive around the beautiful track and enjoy the view of the buildings and surrounding nature. Different sounds can be heard while driving the vehicle. The engine can be heard when accelerating the vehicle and if the player turns too fast the tyres will lose grip and skidding sounds can be heard. When the player goes inside a tunnel the audio gets distorted in a realistic way to make the player really feel like they are there. A picture of a part of the Forest track can be seen in Figure 6.1.

The Forest track was created to explore how participants would react to having minimal game elements but having a realistic and beautiful landscape to look at and drive around. There are no clear goals or objectives in this track; the player can do as they please. The vehicle is a Go Kart which the player can control. This vehicle behaves in a realistic way. Each tyre is realistically controlled by a suspension system and can also lose grip on the track. A toque force is applied to the back tyres which make them rotate, this is what makes the vehicle move forward. The player can choose how much force they want to put into the tyres, they do this by adjusting how hard they press the trigger button on their controller. This type of control was implemented to work just like a normal gas pedal on a real car. The intensity of the steering can also be adjusted by the degree the player moves the joystick horizontally on the controller.

6.1.2 City Track

The City track is set in a futuristic city environment. The track goes through the city's many different narrow alleyways. Various shops and neon lit street signs can be seen along the side of the different styles of buildings. Cables, pipes and walkways stretch above the track from one side of the street to the other. Small harmless robots are moving around the city and tall skyscrapers can be seen in the distance. The player has the ability to use a VR headset and an Xbox controller to control a realistic vehicle. The player is put inside this vehicle which is positioned in front of a red light. When they are ready, a countdown is started. When this countdown ends the light goes green, upbeat music starts playing, and a timer hanging on the side of the wall starts counting the amount of seconds that have passed. The player now has the goal to drive around the track as fast as possible. They have the ability to boost their vehicle, but only if they have picked up enough gas canisters to fuel their boost. The track contains different shortcuts for the player to discover while driving. Also, a ghost driver will appear which mimics the player's best performed lap, making racing around the track feel more engaging. A picture of a part of the City track can be seen in Figure 6.2.

The City track was created to explore how participants would react to having to race against themselves in an engaging and futuristic-looking environment. The aim was that the controls would feel realistic, the controls were thus implemented to behave the same way as the vehicle in the Forest track, with the addition of the ability to boost. The boost makes the vehicle go faster for a short period of time. The aim of the environment is to be visually realistic while also being abstract and unfamiliar in some way. Several element are included in the track to make the player feel like

Figure 6.2: The City track lets the player experience the thrill of racing in a futuristic city

they are in a racing environment, these elements are: a countdown timer, a ghost player, gas canisters, and the ability to boost. These elements will be described in detail now.

A countdown timer goes off before the player starts controlling the vehicle. A diegetic visual of a countdown timer is also present hanging above the player. A total of four diegetic lap timers are placed around the track. These lap timers display the current lap time, and a split time which shows the best time from the start of the lap to that checkpoint.

A ghost player records the player's position and orientation during a lap. If the player finishes a lap and it is a new record, the recording will be saved and played back. This will allow the player to see how they drove on their best performed lap and compete against themselves. The ghost model is made as a transparent version of the player vehicle model.

As stated previously, the player has the ability to perform a boost to make the vehicle go faster for a short amount of time. They can, however, only do this if they have enough boost fuel. The player can get boost fuel by picking up gas canisters which can be collected at certain parts around the track and will fill the fuel meter. The canisters will spawn slightly to the side of the track, so that the player will have to make an extra effort if they want to be able to boost. Each time the player starts a new lap, new canisters will spawn in the same positions. The canisters can be collected by the player driving into them with their vehicle. The player can see the amount of fuel boost they have available by looking at a fuel meter displayed below the steering wheel of the vehicle. The player can decide whether to boost at any time with a press of a button on the Xbox controller, the boost meter will then get used and the vehicle will go faster.

Figure 6.3: The Space track lets the player experience the crazy possibilities that Virtual Reality can provide

6.1.3   Space Track

The Space track is set in a deep space environment, going outside the normal boundaries of reality by exploring three dimensional space. The track twists and turns in various different ways and it is impossible to know which side of the track is pointing up. Planets, stars, and asteroids can be seen all around the environment of the track. When the user starts playing, they have the ability to use a VR headset and an Xbox controller to control a vehicle with physics that do not resemble that of the real world. This is because the vehicle is drawn into the surface it is driving on, making it able to drive on any surface, regardless of its orientation. This makes it possible for the player to traverse the crazy track. The player is also equipped with laser glasses, these special glasses allow the player to shoot lasers in whatever direction they are looking. The goal of the Space track is for the player to gain as many points as possible. The player can use their special laser glasses to shoot asteroids which will give them points. Asteroids can explode into smaller asteroids and crash onto the track. Additional points can be gained through the collection of coins spawned on the track. The Space track can be seen in Figure 6.3.

The Space track was created to explore how participants would react to having an out of the ordinary experience with an unrealistic, crazy environment around them. The vehicle controlled by the player is not the same as on the other two tracks. This vehicle is less realistic by having the ability to drive on any oriented surface; it will rotate itself depending on the orientation of the surface it is driving on. The vehicle was made in such a way that it is easy to control; it does not have any suspension system or the ability for the tyres to lose grip, unlike the other two vehicles on the Forest and City track. The way the vehicle moves forward is by adding a force to the whole of the vehicle body, instead of just the back two tyres as with the Forest and City vehicle. The steering works much the same way; a rotation force is put

Figure 6.4: The score the player accumulates can be seen on the vehicle

on the whole of the vehicle body which is very different compared to the Forest and City vehicle where just the front two tyres are rotated. The vehicle is controlled this way because it further simplifies the way it moves and behaves. As for the vehicle model, it is similar to the other two tracks, however, the wheels are rotated ninety degrees to show that it is "hovering" in the air. The track twists in different ways, this makes the vehicle sometimes drive upside down or sideways, however, the controls do not change while it is in this orientation, from the players point of view, only the environment around them is twisting and turning.

As stated earlier, the goal of the track is to have the player accumulate the most amount of points. They can do this by shooting asteroids, gaining five points for successfully hitting an asteroid with their laser. This laser can be aimed by the way the player is looking with their head. If an asteroid gets hit by a laser, it breaks into smaller pieces and if a smaller piece gets hit by a laser, it explodes by showing some particle effects and disappearing. Asteroids spawn at the start of the experience and are seen floating on top of and around the whole of the track. Some are stationary with a slight constant rotation, while some asteroids crash into the track and break apart in front of the player while they are driving around. Furthermore, coins are spawned on the track which the player can pickup and will give them two extra points, this is to incentivise the player to drive around the track while shooting the asteroids. The player can see the amount of points they have in front of them in the vehicle, an example of this is seen in Figure 6.4.

6.2 Guidelines

A total of eight guidelines were created for future researchers and designers to consider when designing a virtual reality racing experience in order to increase the feeling of immersion for a various amount of experience levels. The future researcher or designer can use the guidelines and the examples provided in this thesis as a reference and an inspiration for creating their own immersive VR racing experience.

When designing an immersive virtual reality racing experience for a variety of ex-

perience levels, consider:

6.2.1   The type of player one is designing for

It is very difficult to make a singular racing experience which will immerse every player. Players have different experience levels and preferences on how they play and what kind of environment they want to race in. Five main player types were identified when performing an informal thematic analysis on the answers that were acquired from the evaluations. This approached allowed the data that was collected from the evaluations to determine the theme of the player types, rather than using existing themes based on theory or other knowledge. The designer could choose to design for a specific player type, or to provide user-adjustable content in the experience in order to tailor to several player types. Note that this is not a complete list of player types, it is only a suggestion of how any one player can be categorised considering what was found in this study.

Reality Enjoyer: These are the players that value the realism of the experience. They enjoy driving fast on realistic tracks and having precise and responsive controls for their vehicle. They do not need many game elements or mechanics to keep them engaged and immersed, as they are satisfied with the simulation aspect of the experience. However, they also appreciate some thrill and challenge that can make them feel excited and immersed.

The evaluations showed that these players valued the importance of realistic controls on the vehicles in the Forest (6.1.1) and City (6.1.2) track. They continuously stated that the controls should be more realistic as they were constantly distracted by the unnatural behaviour of the vehicle.

Rear View Relaxer: These are players that prefer to relax and enjoy the ride. They drive at a moderate pace and like to look around the scenery and environment. They get immersed through their senses and emotions, as they appreciate the beauty and atmosphere of the experience. They also like to have some minor game objectives or feedback that can give them a sense of direction and accomplishment.

The evaluations showed that these players preferred to play the Forest (6.1.1) track, as it had the most scenic and varied environment. They also liked this track due to its lack of challenge and game elements. They did however state that some minor goals or objectives should be added to the Forest track to make it more interesting.

The Casual Gamer: These are players that are not too picky or demanding about the details of the experience. The important thing for them is that they have fun. They want the experience to be accessible and simple, so they do not have to struggle with learning or using the controls.

This player type is supported by the fact that some evaluated participants had no strong opinion about any of the three tracks, most of their comments were

about the ease of use of the controls and the engagement aspects on the City (6.1.2) and Space (6.1.3) tracks.

Arcade Admirers: These are players that seek novelty and excitement in the experience. They want something out of the ordinary, something that can exceed their expectations and imagination. They want the experience to let them be involved in things that are not possible or common in reality, such as power-ups, abilities, or crazy tracks.

Evaluations showed that these players preferred the Space track (6.1.3), as it had the most novel and exciting game elements and track.

Competitive Challenger: These are players that enjoy competing and challenging themselves in the experience. They like to test their skills and abilities against other players or against their own records. They get immersed through their motivation and achievement as they strive to improve and excel. They also like to have some competitive game elements or mechanics that can enhance their immersion and challenge, such as leaderboards.

The evaluations showed that these players especially liked the City track (6.1.2), as it had the most competitive nature out of the three tracks due to various game elements such as the timer and ghost player. This was also obvious through observations as when the player saw that the ghost player went ahead of them, they got frustrated and started focusing more on their driving.

The experiences available in the Sim Racing games taken up in Section 2.2 are specifically tailored for players who may be Reality Enjoyers or Competitive Challengers. These players like to drive in a realistic way and in a realistic environment which may seem familiar to them. For this reason, most of the tracks in sim racing games are tracks taken from famous tracks in real life, or tracks which resemble generic race tracks in real life. Many competitive modes are also available such as different types of leagues players can compete against each other in, or time trials.

The approach of designing an experience for Arcade Racing games is very different; these types of experiences are made with a different kind of audience in mind. We can for example see this in the tracks of Mario Kart™ 8 Deluxe (2.3.1). Many of the tracks are not similar to the real world. The track Rainbow Road is set in space, and another track Waluigi Pinball makes the player drive around in an enormous pinball machine. There are also many different game elements present in the game. The player can use different kinds of abilities which make the game more engaging in a unique way.

More details about the design of the track and the design of game elements are found in Sections 6.2.7, and 6.2.8 respectively.

6.2.2   The amount of motion the player is experiencing

Having a lot of motion will increase the likelihood of the player experiencing cybersickness. This will prevent the user from playing further which will thus prevent them from becoming immersed. As described by Seridakis *et al.* [34], controller based locomotion led to the highest amount of cybersickness compared to stationary and real life walking based locomotion. Furthermore, Seridakis *et al.* also found that gaming content has the highest amount of effect on cybersickness compared to 360 video, minimalist and scenic content. Cybersickness was found to be a highly subjective factor in the evaluations. Most participants said that they were experiencing some level of dizziness or sickness, while some said they did not notice it at all. It was also found that the Space track (6.1.3) caused the most amount of cybersickness. This could be because it was the track where the participants were exposed to the most amount of motion, or perhaps that a culmination of cybersickness had been reached over the course of playing the previous two tracks, as the Space track was played last in the evaluation.

6.2.3   The audio that is being played

Audio will further enhance the experience and help the player get immersed in the environment. The audio should match the visuals in the environment to make them believable.

This guideline is supported by, Gallacher [58], Gormanley [59], and Sinclair [60]. Sinclair [60] describes the importance of the consistency between audio and visual information. He states that 'as sound designers, it is therefore crucial that we be consistent in our work. This is not only because we can as easily contribute and even enhance immersion as we can destroy it, but beyond immersion, if our work is confusing to the player, we take the risk of having the user discard audio cues altogether' [60, p.16].

One can see many examples of immersive audio being present in existing racing titles. This is especially true for Sim Racing games (2.2), where the goal is to make the experience as realistic as possible. Many sounds come from the vehicle itself such as engine and tyre sounds. But several other sounds can be present as well such as crowd cheers and weather sounds. As for arcade racers, a large variety of sound effects and music can be heard while playing. Sound effects are, for example, played when using and obtaining power-ups, while unique theme songs can be heard with each different race track.

Participants in the evaluations said that the audio helped them to feel immersed within the environment. This was especially true with music and spacial sound effects such as the change in engine sound when going through the tunnel in the Forest track (6.1.1).

6.2.4 The challenge of the experience

The challenge of the experience is an important factor that influences the level of immersion and enjoyment of the player. If the player experiences too much difficulty when playing the game, they will get frustrated and lose their sense of immersion. The challenge of the experience can be affected by various factors such as vehicle controls, track design, design of game elements, and what the goal of the experience is. Details about the significance of vehicle controls are taken up in Section 6.2.5. What to consider regarding the design of the track and game elements are taken up in Section 6.2.7 and Section 6.2.8 respectively. This guideline is supported by the concept of flow and DDA which are detailed in Section 3.2 and Section 3.5.

During the evaluations, many participants stated the importance of the difficulty matching their skills. Some participants stated that they would like the tracks to be more difficult, while others stated that some tracks were too difficult for them. This suggests that it is important for players to be able to choose their own difficulty, or that the difficulty is changed dynamically as is done in DDA (3.5).

6.2.5 How the vehicle behaves according to player input

The player should feel as though they have full control over the vehicle and that the vehicle behaviour is consistent and predictable. The vehicle behaviour should match the player's expectations and preferences as described in Section6.2.1, which may vary depending on their level of experience and the type of racing experience they prefer. If one is aiming to design for a variety of player experience, the controls should be intuitive and easy enough for inexperienced players to use, but also challenging and realistic enough for experienced players to enjoy.

For example, in the second evaluation, the players controlled the vehicle by steering with a VR controller. It was found that this form of control was too difficult and unnatural for players without much VR experience. These players became frustrated with the experience because the vehicle did not behave as they thought it would which, as a result, affected their immersion negatively. As for experienced players, during the final evaluation some said that the vehicles in the Forest (6.1.1) and City (6.1.2) tracks were not behaving realistically enough in relation to their input.

6.2.6 How the behaviour of the vehicle is communicated to the player

The player should be able to understand and anticipate the vehicle behaviour based on clear and effective feedback. The feedback should be easy and intuitive to perceive and use, without requiring too much effort or attention from the player. The feedback should also complement the vehicle behaviour, as described in Section 6.2.5. When doing the evaluations, participants stated that when the vehicle behaved unexpectedly they got confused and frustrated. Some also said that it required too much effort to look at the boost meter.

We can see this being followed in Sim Racing games (2.2) as they use realistic
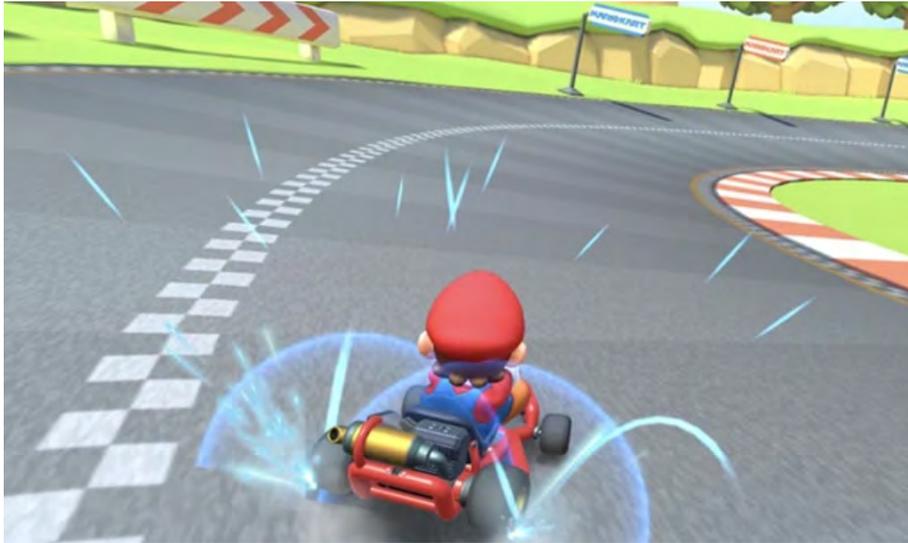
Figure 6.5: A player performing a mini-turbo in Mario Kart™ Tour

and consistent feedback to communicate the vehicle behaviour to the player. For example, if the tyres lose their grip and the vehicle starts sliding one can hear audio feedback. The same feedback can also be communicated through the controller itself by vibrations or - if the player is using a steering wheel controller - on the wheel itself by vibrations or the tension of the turning.

An instance of appropriate feedback in the Mario Kart™ Franchise is seen when generating a mini-turbo. This is when you perform a drift for an extended amount of time in order to get a speed boost. This mini-turbo indicator is cleverly displayed where the wheels contact the road, to signal to the player that they can get a boost after their drift. The indicator changes colour depending on how long one holds the drift, which will increase the intensity of the boost after the drift. An example of this can be seen in Figure 6.5.

6.2.7 The design of the track

The way the track is designed has a big impact on how the player feels like when driving around it. One should consider different aspects which can have an effect on the difficulty of the track such as the amount of turns there are and how sharp these turns are. The way the track is designed changes how fast the player can drive and how many turns they have to do. This also affects how many times the player has to brake and accelerate. Having a more difficult track to navigate can make it more fun for experienced players to play as there is a higher challenge level, however, it will also make it more difficult for inexperienced players. This also depends on what player type one is designing for, this is taken up in more detail in Section 6.2.1.

Sim racing games (2.2) offer a wide variety of tracks for players to choose from. These tracks range from short with a lot of turns to long tracks with very few turns. This is to tailor to different experience levels to make it fun and immersive to play for everyone. The same can be said for arcade racing game tracks. The

majority of tracks in Mario Kart™ 8 Deluxe (2.3.1) are easy to drive on, with some tracks being harder than others. Most tracks also offer shortcuts to give experienced players a reward for their knowledge of the track. Shortcuts were implemented in the City track (6.1.2). During the evaluations, most participants did not notice these shortcuts, however, the participants that did said that they were a great addition and it made the track more interesting to drive around.

Looking at previous studies, Surarerks and Kotrajaras [56] suggested that experienced players enjoy tracks with a high degree of changes in the layout of the track. This contradicts what Galdieri *et al.* [57] found. They discovered that players prefer fast circuits regardless of length, while disliking circuits with too many corners. What was found in conducting evaluations was more inline with the findings of the Surarerks and Kotrajaras study. The City (6.1.2) and Forest track (6.1.1) were both created with a variation in difficulty and style. The City track shown in Figure 6.7 was designed to include many sharp turns which increase its difficulty. The Forest track on the other hand, shown in Figure 6.6, has few turns which are smooth, decreasing its difficulty. The evaluations showed that the majority of experienced players said that they preferred the City track because of its difficulty, while some inexperienced players said they found the track too difficult.

Figure 6.6: The Forest track as seen from the top, is easier to drive on, as it has wide turns

Figure 6.7: The City track seen from the top. It has many sharp turns, making it harder to drive on

6.2.8   The design of the game elements

Game elements will change the feel and difficulty of the experience drastically thus one should consider to what extent one should include game elements and what goal they are trying to accomplish. This also depends on what player type one is designing for, this is taken up in more detail in Section 6.2.1.

For example, when looking at Sim Racing games (2.2), not a lot of game elements are included. This is because the goal of these types of games is to immerse the

player through the sense of realism they create. The game elements included are thus related to making the experience similar to real life racing. This is different to Arcade Racing games. In these types of games, many different types of game elements are included to make the experience more exciting and engaging. They are also included to make the experience unique to that particular game.

Two of the developed tracks included various amounts of game elements. The City track (6.1.2) included elements which would engage the player and encourage them to complete a lap as fast as possible. The Space track (6.1.3) included game elements which would engage the player by letting them gain points in various ways.

For example, the robots moving around on the City track were taken note of by some players during the evaluation. Some players tried to avoid them at first, while only later realising that they were harmless and confused why they were there. Not a lot of thought was put into what the aim of the robots would be and as a result they made the players confused.

7

Discussion

In this chapter, the methodologies, process, results, ethical aspects, and future work will be discussed

7.1 Method

The method used in this study as gone through in detail in Section 5.2.2 was followed to a great extent. This section will discuss the pros and cons of using the method described.

Working with an iterative approach was very beneficial and helped the study and prototype move in the right direction. This was mostly due to the three evaluation sessions that were done. Many good ideas were gathered and discussed from these sessions and it helped make the goal of the different tracks clearer. It also helped to decide what aspects to add or change in the prototypes. For example, the VR steering was initially planned to be in the final evaluation, however, after the second evaluation (5.4.4) it was clear that this type of interaction would not work as participants had many difficulties with the controls. If the second evaluation was not done, it could have drastically changed the amount of quality feedback that was attained from the final feedback session, as participants would have had much difficulty driving around the track normally.

Dividing the work that has been done in this study into the distinct activities discovering, design, prototyping, and evaluation has been of much help. When working on any of these activities it was easier to understand what the aim was of the activity, and to see the bigger picture of why the activity was being done. The scrum activities described in Sections 4.6.1, 4.6.2, and 4.6.3 were done in the first and second sprint, however, the effort it took to do these activities was not justified by the results they provided. It was thus decided that the Scrum would not to be done after the second sprint. The reason for this could be because the Scrum project management technique is designed to be used by a moderately sized team. It has numerous overhead tasks such as the different scrum activities. It could instead have been beneficial to follow a different but similar project management technique called Kanban, which does not have as many overhead tasks as the Scrum technique.

The initial pre-study as described in Section 5.2 was beneficial as it helped with gain-

ing valuable knowledge about relevant topics in the field. This made the methods and theories used in the study more sophisticated by being supported by previous research. It also resulted in the process being more clear and thus also easier to execute.

Creating experience goals as taken up in Section 5.3.1 was a great way to start the first phase. It made it possible to focus on what really mattered with the experience and to understand what the goal of it was. Further defining each experience goal with concrete examples of how these goals could be accomplished helped kick-start the development of the prototype with a view of what could be included in the experience.

As outlined in Section 5.2.2, the study was initially planned to include DDA (3.5) to help immerse the player in the experience. However, the study was pivoted and it was decided that three different experiences where going to be made. Looking back on this pivot it seems as though it was a more drastic change than was first anticipated. Making the tree different experiences has produced many more views and interesting observations about what different players like about the different experiences. Had it not been for this pivot, the end results could have been less broad and more focused on how DDA effected immersion. This would not necessarily have been a bad result, however, I argue that the current results better answer the research question, and thus the pivot done was an excellent choice.

7.2 Results

In this section, the final results produced during the study such as the prototype and guidelines will be discussed.

7.2.1 Prototype

Three different experiences were created in order to explore what aspects should be considered when designing a VR racing experience. The Forest track (6.1.1) was created to explore how participants would react to having minimal game elements but having a realistic and beautiful landscape to look at and drive around. The City track (6.1.2) was created to explore how participants would react to having to race against themselves in an engaging and futuristic looking environment. The Space track (6.1.3) was created to explore how participants would react to having an out of the ordinary experience with an unrealistic, crazy environment around them. Surprisingly, when participants where asked to answer the question 'To what extent did you feel like you were really in the game?' the majority of the participants said that all three experiences felt equally as real, even though they said that they where engaged in each track differently. This could suggest that having engagement aspects in the experience has no effect on immersion. I argue however, that participants need to be engaged to be able to feel a higher sense of immersion. Participants might have said that they where immersed in each of the experiences, but they where subconsciously more immersed in the experiences where they were engaged. This

observation could also have been due to a misunderstanding with the evaluation questions by the participants. More qualitative questions could have been asked about immersion on each track to better understand if engagement actually had an effect on the participant's feeling of immersion. If one considers the taxonomy created by Nilsson *et al.* [15] - which was briefly introduced in Section 3.1 - the immersion area that the question, 'To what extent did you feel like you were really in the game?', explores is immersion as a property of the system. In other words, the question asked to what extent the system (game) gave the player a sense of realness. In the case of a participant saying that all experiences gave them a sense of being in the game, this meant that the system seemed real enough to give them a sense of immersion. The other dimension of immersion Nilsson *et al.* take up is immersion as a response to challenges demanding use of one's intellect or sensorimotor skills. This area of immersion is much similar, if not identical to the extent a participant is engaged in the experience. I thus argue that, because engagement aspects were explored in the questions asked in the evaluation, and participants stated that they had different senses of engagement, this means that engagement does have an effect on immersion.

An interesting area to discuss is what defines a racing experience. The word 'experience' has been used throughout this thesis instead of the word 'game'. This has been done because an experience is more open-ended and thus also more broadly defined. For example, if we look at the Forest track, it has no objectives and nearly no challenges apart from learning the controls. One could argue that it is a game, but I would argue that it is not, it is instead an experience as it lacks any clear goal or challenging elements. However, is it a racing experience? The definition of a race according to Oxford Languages [61] is 'a competition between runners, horses, vehicles, etc. to see which is the fastest in covering a set course'. The Forest track does not fit within this definition and this could therefore be a reason why it got such negative views from some of the participants who played it. Their expectations could have been that they were going to have fun by playing a racing game, so when they realised it was not, they got disappointed and thus also bored. This could also be the reason why the City track had more positive comments, as it included more elements which make it more similar to a racing experience.

7.2.2 Guidelines

The final guidelines, described in detail in Section 6.2, outline what designers and future researchers should consider when designing a VR racing experience. However, these guidelines had to be kept very general due to the drastic differences between the tracks that were created. The initial idea was to have smaller changes between each track as one could then evaluate the tracks to precisely understand which elements and features had the most impact on immersion. However, this was not a valid option, as there are too many variables to consider and no accurate or valid results would be created. It was thus decided to have drastic changes between the different tracks in order to investigate the research question on a broader level which resulted in more general guidelines.

It was found that different types of players have different preferences and expectations for immersion, these are what the different player types taken up in Section 6.2.1 resemble. However, these player types do not consider the context the player is in, one could argue that external factors such as the environment the player is in, the mood of the player, or the hardware they are using could have an important factor on immersion. For example, a player might feel more immersed if they are sitting alone inside a room compared to having other people with them.

Cybersickness has been a big factor in this study and thus could have had an effect on the final guidelines. During evaluations, several participants had to stop playing due to cybersickness. Some participants thus did not spend enough time playing in order to take note of all the elements in each track. Some also stated that they were deliberately driving and turning slower to decrease the amount of motion they were experiencing. This factor could have been avoided by discarding the answers of the participants that had to stop playing before the minimal required time. However, if this would have been done, only four participant's answers would have been valid, it was thus decided to keep all answers. Furthermore, considering that the majority of the participants got effected, cybersickness is clearly an important factor to consider if it prevented the players from playing the experience, and thus also preventing them from feeling immersed.

The reason participants felt cybersickness was not clear. Some said they felt the sickness more when they started playing the experience, while it gradually decreased the longer they played. With some participants, the sickness was negligible when they started playing the first track but gradually increased the longer they played. The majority of participants also stated that the Space track was the track that caused more cybersickness compared to the others. One explanation for this is that some participants are more prone to sickness compared to others, and some participants get used to the virtual environment while others can not adapt and thus the sickness gets worse. Another explanation could be the difference in content and vehicle behaviour on each track. The Space track required the participants to do vigorous head movements while also having a track that did many twists and turns in 3D space, leading to the participant experiencing a lot of motion. These findings highlight the complex nature of cybersickness and suggest that more factors than originally anticipated can have an effect on the amount of cybersickness an individual is experiencing.

7.3   Ethical Considerations

As discussed previously, cybersickness has been a major factor that has been dealt with in this study. However, although efforts were put into trying to reduce the amount of cybersickness the participants could be experiencing, many participants still felt the cybersickness to an extent. Cybersickness has been handled by making it clear to the participant before beginning the evaluation that they could experience cybersickness, and that they could stop playing at any time if they felt any discomfort. To reduce the chance of cybersickness, one could instead play the ex-

perience on flat screens. This could however have an impact on immersion, as has been suggested by Walch *et al.* [62]. Future hardware could also reduce the amount of cybersickness as different latencies can be reduced, which has shown to be one of the causes of cybersickness [63].

When considering accessibility, each track requires the participants to wear a Head Mounted Display (HMD) and to be able to operate an Xbox controller. Participants in the evaluations had no problems with accessibility, however, it may pose challenges for users with mobility impairments or visual impairments. That being said, the experience may also provide an opportunity for users who are unable to drive a vehicle in real life to enjoy a simulated driving experience in a safe and controlled environment.

Looking at the accessibility of the different tracks one can argue that they differ from each other. The Forest track (6.1.1) is undoubtedly the most accessible track. It does not force the player to do anything, allowing the player to play at their own pace, which leads to the track being the least cognitively and physically demanding. The City track (6.1.2) however, does force the player to drive the vehicle quickly through different elements such as the upbeat music, timers, speed boosts and ghost player and requires quick reactions with the sharp turns. This makes the track more cognitively and physically demanding as the player has to think about more things and control the vehicle at a fast pace, making the track less accessible in general. The Space track (6.1.3) is arguably the track that is the least accessible out of the three tracks. It encourages the player to move their head around vigorously to shoot at the different asteroids which could have a short or long term negative effect on the player's neck. Participants with mobility impairments could also have great difficulty doing these active movements with their heads. To conclude, the Forest track is the most accessible with no enforced requirements, allowing players to proceed at their own pace. The City track is less accessible due to the enforcement of quick driving, multitasking, and faster gameplay elements. The Space track poses the greatest accessibility challenges, requiring vigorous head movements and presenting difficulties for individuals with mobility impairments. Overall, the Forest track is the most inclusive, while the City and Space tracks have higher accessibility barriers.

Another ethical issue to consider is that the experience can influence the players emotions and behaviours without their awareness or consent. For example, although the City track is specially made to increase the challenge and excitement the player is experiencing, it can also cause them to feel negative emotions such as frustration and stress. Furthermore, because the experience can create an intense and vivid experience it may trigger or leave traumatic memories on the player.

7.4 Future Work

This chapter will discuss some possible directions for further research and development for this thesis such as adding a multiplayer mode, increasing inclusiveness, and improving the hardware and interactions.

7.4.1 Multiplayer Mode

As taken up in Section 1.2, a limitation was set on the study to only implement and evaluate a single-player experience. As found by Winkler *et al.* [64], social interaction and shared experience was one of the three main categories which was a factor of immersion. Therefore, a possible direction for future work could be to design and implement a multiplayer mode that can support social interaction and competition among players on top of the developed experience, and see how it can impact immersion.

A multiplayer mode could for example allow players to create their own avatars and use voice chat or gestures to communicate and interact with each other. Players could also compete or cooperate with each other on different types of tracks and environments that offer a variety of game modes. For instance, the Forest track could be further developed to allow players to explore the environment together. The City track could also be further developed to include the racing of different players simultaneously and the player could have the ability to use different types of power-ups to boost their performance or sabotage opponents. Additionally, players could see their scores and rankings on leaderboards to further increase the amount of social aspects.

The multiplayer mode could have several benefits on the player's immersion. By allowing the players to interact and compete with others, they might experience more engagement elements which may increase their involvement in the experience and thus make the player feel more immersed. Having players collaborate and working together could give room for social bonds and friendships. These aspects could make the players feel more immersed by making them more connected to the virtual environment and the other users.

7.4.2 Increasing Inclusiveness

Another limitation of the study is that it only focused on a specific user group. Although users with different preferences in terms of play style were identified, it did not consider users with differences in abilities, other types of preferences, or backgrounds. These users may face potential challenges in accessing or getting immersed in the experience. In order to better answer the research question, one should not neglect these mentioned differences in users. A possible direction for future work is thus to make the experience accessible and inclusive for users with different abilities, preferences, and backgrounds.

A possible way to make the experience accessible and inclusive for a variety of different users is by further developing different types of interaction and feedback techniques. For example, users with visual impairments could use eye tracking or audio cues to navigate through the virtual environment by controlling the vehicle. Furthermore, users with mobility impairments could use haptic feedback or gesture recognition to interact with the vehicle.

Another possible way to improve the experience is to use diverse or customizable

content that can appeal to users with different languages and cultures. For example, users could choose how they want the style of the environment to look and what language is used in that environment. This could for example change the style of buildings that are displayed in the City track, and change the language that is displayed on the different signs found in the environment.

Some possible benefits these implementations can provide is that users with different abilities will have access to immersing themselves in the experience without feeling excluded or disadvantaged. Furthermore, by providing diverse or customizable content, users with different preferences and backgrounds could make the experience match their interests and values, making them feel more connected, engaged, and thus also immersed in the experience.

7.4.3 Hardware and Interactions

In this study, only two controller types were tested on users, it would be interesting to see how other controller types or interaction techniques would have an effect on immersion. Another direction for future work would thus be to investigate different types of interactions and hardware technologies such as different devices and controllers and their effect on immersion.

For example, one could implement the different types of interaction techniques which where considered during this study - these are taken up in Section 5.4.1.2 - and compare them to each other. The different interaction techniques could have their own possible benefits. For example, the steering wheel controller could increase the sense of realism of the interaction by mimicking an actual driving experience, while the VR controller may create a sense of novelty and excitement. One could also explore different types of hardware entirely by converting the experience to work in augmented or mixed reality. For example, a mixed reality version of the experience could take place on a real race track within a real race car. Digital elements could then be overlaid onto the real world, such as holograms of other racing cars, gaming elements such as coins and power-ups, and the environment around the player could also be made fully digital.

The benefits these implementations provide could include gaining a better understanding of what type of interaction techniques players prefer, or which ones increase immersion. This could help to design more immersive and user-friendly racing experiences that suit different types of players. Converting the experience to another reality could also be a benefit by enhancing the players sense of immersion by integrating the real and virtual world.

8

Conclusion

This thesis has explored the design and implementation of a virtual reality racing experience for a variety of player experience levels through the development of three uniquely designed tracks. The research question was the following:

> *What should be considered when designing a virtual reality racing experience to increase the feeling of immersion for a variety of experience levels?*

To answer this question, the thesis followed an iterative design process that consisted of four phases: discovering, designing, prototyping, and evaluating. The final results led to the creation of EnviroCircuit, which is a VR racing experience, containing three unique tracks: The Forest, City, and Space track. The Forest track lets the player sit back and enjoy their surroundings. The City track lets the player experience the thrill of racing in a futuristic city. The Space track lets the player experience the crazy possibilities that VR can provide. EnviroCircuit was tested with users, resulting in a set of eight guidelines for designing immersive VR racing experiences. The guidelines which were created are the following:

Consider the type of player one is designing for: Players have different experience levels and preferences on how they play and what kind of environment they want to race in.

Consider the amount of motion the player is experiencing: Having a lot of motion will increase the likelihood of the player experiencing cybersickness, which will decrease the sense of immersion.

Consider the audio that is being played: Having the right audio will further enhance the experience and help the player get immersed in the environment.

Consider how the vehicle behaves according to player input: The player should feel like they have full control over the vehicle and that no other factors which they are not aware of are effecting the vehicle's behaviour.

Consider how the behaviour of the vehicle is communicated to the player: The player should be able to understand and anticipate the vehicle behaviour based on clear and effective feedback.

Consider the design of the track: The way the track is designed has a big impact on how the player will drive around it, one should consider different aspects which can have an effect on the difficulty of the track.

Consider the design of the game elements: Game elements will change the feel and difficulty of the experience drastically. One should consider to what extent one should include game elements and what goal they are trying to accomplish.

Consider the challenge of the experience: If the player faces too much difficulty when playing the experience they will get frustrated and lose the sense of immersion

The thesis contributes to the field of VR design by providing insights into how immersion can be enhanced in VR racing experiences and by presenting a functional prototype that explores these insights. The thesis also suggests some directions for future work, such as exploring multiplayer aspects and increasing inclusiveness.

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A

Appendix 1 - Persona and Scenario

Name: Steve
Age: 32
Occupation: Sales Executive
Location: Urban area
Personal interests: Technology, sports, gaming, and immersive experiences
Background: Steve is a young professional who is passionate about staying up to date with the latest technological advancements. He enjoys trying new things, especially those that offer immersive experiences that allow him to escape from the everyday hustle and bustle of life.
Lifestyle: Steve lives a busy life, with a demanding job and an active social life. He is always on the go and values convenience and flexibility in all aspects of his life. Steve typically uses public transportation or ride-sharing services to get around the city but sometimes needs a car for weekend getaways or trips to visit family. He loves trying new things and enjoys pushing his limits.
Driving preferences: Steve enjoys driving fast and has an interest in sports cars. He is drawn to the latest technology features and values a vehicle that is both powerful and efficient. He is also interested in the latest electric and hybrid vehicles and their environmental benefits.
Gaming experience: Steve is an enthusiastic gamer with a particular interest in FPS games. He owns a PS5 enjoys playing on it when he has the time. He is often on the lookout for new titles to add to his collection. Steve has little experience with VR headsets, however, he once used a VR headset at his friend house and enjoyed the experience and has been considering buying one himself.

The scenario created to better understand the design space

Steve goes into the Lynk&Co club for the first time and meets the employee at the bar. They talk for a bit and the employee tells them about the company, what they stand for etc. After a while they are done talking the employee says that Steve can have a look around the club and explore. Steve is excited to explore the space, after a while he sees a big racing seat with a VR headset next to it. He wonders what it is and asks the employee. The employee explains that it is the new racing experience simulator called Conscious Racer and says that Steve can try it out Steve is excited and asks more what the experience is about. The employee says that he can experience how it is feels like to be in a racing car and that there is a fun "Lynk&Co" twist on it to make the experience unique Steve goes to sit in the simulator and puts the VR headset on. The system welcomes him, because it is his first time, the system asks him to select a car model from a set of Lynk&Co cars. It then asks Steve to adjust the car to his liking. When Steve is done customizing his car he can start racing. Steve is blown away by all the things that is happening in the simulator. He is carried away by all the things flying around the car, there are a lot of beautiful lights around the track. The headset Steve has on is filled with noise of the environment around him, he can hear the crowd, and the engine starting from the car. Steve really feels like he is in a different world. Steve starts driving around the track. At first, Steve needs to get used to the controls. It requires him to focus hard, but it is not to difficult for him, the track is just the right difficulty so Steve does not lose focus or get frustrated. After a while it gets easier, Steve is getting pretty relaxed because nothing new is happening. But now he sees a weird object on the track, he is curious about what it is and is drawn into driving into it. As he does the car suddenly goes really fast, Steve gets excited again as he is not used to this new thing happening. Suddenly, things are crashing into the road and blocking his way. Steve needs to be alert to not crash into the objects, he continues to rive with caution around the track. After some time Steve's time is up and takes off his VR headset. For a slight moment Steve had forgotten that he was at the Lynk&Co club and sitting at the simulator. At this moment Steve feels a rush of excitement, he has no idea if he had been playing for 5 minutes or 5 hours. He will remember this precious moment at the Lynk&Co club and tell his friends about this amazing experience.

B

Appendix 2 - Consent Form

The consent form used in the final evaluation can be seen on the next page

I am asking you to participate in a research study titled EnviroCircuit, Feeling of immersion in VR racing environments. I will describe this study to you and answer any of your questions. This study is my final Master Thesis and is being led by me, Rik Muijs, a student at the Department of Interaction Design, Chalmers.

What the study is about
The purpose of this research is to examine how one can design and implement a racing experience in such a way as to have a high amount of immersion for people with a variety of experience levels.

What I will ask you to do
I will ask you to play three different VR racing games, each having a unique environment and game elements. You will be playing each game for around 5 minutes. After playing the games, I will ask some questions about your experience with each game. The whole process will take around 30 minutes.

Risks and discomforts
You may experience physical discomforts such as nausea, dizziness, sweating, or loss of balance. These are common side effects of using a VR headset.

Benefits
By participating you are directly contributing to the results of the study. The information gathered will help with getting a better understanding of what aspects of an immersive racing experience are important to include, or not to include to get the feeling of immersion. This will make it easier for designers to know what to consider when wanting to develop immersive racing experiences, and as a result make these experiences more easily accessible for people with various amounts of experience with virtual racing.

Privacy
You will be kept anonymous and no sensitive or personal data will be collected. The data that is collected may be included in the final report such as quotes and comments.

Taking part is voluntary
Your participation is voluntary, you may refuse to participate before the study begins or discontinue at any time. You may skip any questions that make you feel uncomfortable.

If you have questions
Please ask any questions you have now. If you have questions later, you may contact me at muijs@chalmers.se

Statement of Consent
I have read the above information, and have received answers to any questions I have asked.

Do you consent to the above information and to take part in the study?

Yes ☐   No ☐

Date: _____

C

Appendix 3 - Interview Questions

- **About user**

  - How familiar are you with video games? How often do you play?

  - How familiar are you with immersive experiences? Can be VR roller-coaster rides etc.

  - What is your age?

- **Environment**

  - Which game was most interesting to you? Why?

  - What aspects did/didn't you like about the game?

  - What was it that was interesting? Was it the controls? The amount of visuals there where? The goal? The track?

- **Immersion**

  - **Basic attention**

    * How focused where you on playing the game?

    * How much effort did you put into the game? Did you feel like you put all your efforts?

  - **Temporal dissociation**

    * How long do you think you played for? Did you lose track of time? Why/why not?

  - **Transportation**

    * To what extent did you feel like you were really in the game? Which environment would you say was most effective with this? Why

      · How did you notice that?/Have you had to devote all your attention and concentration to playing?/Did it feel like you were separated from the real world?/Have you ever forgotten that you

are using a controller/HMD?

· Does the game feel real to you?/What would have to be different for it to feel real to you?/In comparison with real racing - what is missing in VR

∗ Did you have the feeling of being there in the virtual environment, was this sense stronger than being in the real world?

- **Flow**

  - **Challenge**

    ∗ Did you find the game challenging? Which one was the most challenging and why?

      · How did you notice that?

    ∗ Did you feel like you wanted to give up?

    ∗ What are your thoughts on the track layouts? Was it difficult or Easy? Fun or boring??

      · Which track design was the most immersive and why?

    ∗ What where your thoughts about the game elements? (coins, fuel, shooting asteroids, ghost player etc." Did one stand out? Did they make the experience difficult or easy? More exciting?

    ∗ When comparing track design and game elements. which one of the two had most effect on you? Why

  - **Experience**

    ∗ Taking into account your previous gaming experience, did you feel like the difficulty was just right?

- **Control**

  - How well could you control the car, how much thought did you have to put into control the car?

  - Do you feel like the controls where natural/realistic?

  - Which car was the easiest/best to control? Why

  - Did the control of the car have an effect on the immersion?

- **Cybersickness**

  - Did you feel any sense of motion sickness? How bad was it?

- **Audio**

– What did you think of the sounds? Where they realistic? Did they fit the environments