TU WIEN Informatics

Entwicklung einer Multiplayer Gaming-Erfahrung im Auto

Entwurf eines Mobile-Spiels: Eine Prototypstudie

DIPLOMARBEIT

zur Erlangung des akademischen Grades

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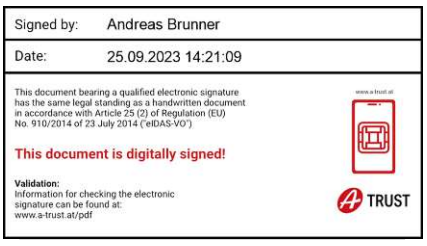

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TU WIEN Informatics

Development of an In-Vehicle Multiplayer Gaming Experience

Designing a Mobile Game: A Prototype Study

DIPLOMA THESIS

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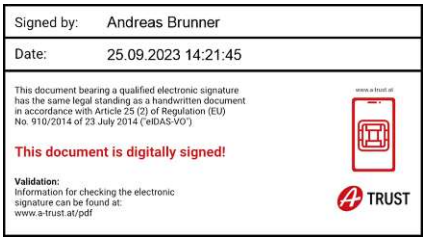

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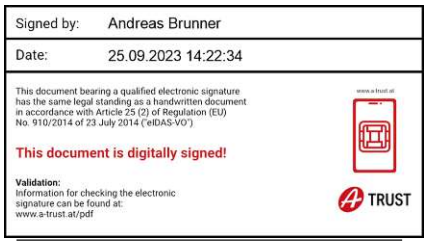

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Andreas Brunner

Danksagung

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Once again, many thanks to all who have accompanied me on this journey.

Kurzfassung

Mobilität ist ein unverzichtbarer Bestandteil des täglichen Lebens. Ob in ländlichen oder städtischen Gebieten, viele Menschen sind auf öffentliche Verkehrsmittel oder das Auto angewiesen, um von einem Ort zum anderen zu gelangen. Vor allem in ländlichen Gebieten lässt sich die Nutzung des Autos kaum vermeiden, da die öffentlichen Infrastrukturen in vielen Ländern nicht gut genug ausgebaut sind, um klimafreundliche Fernreisen zu ermöglichen. Infolgedessen ist die Zahl der Personenkraftwagen in der Europäischen Union in den letzten 10 Jahren stetig angestiegen. Das Hauptproblem bei dieser Entwicklung ist der Ausstoß von Treibhausgasen. Der Verkehrssektor ist einer der größten Verursacher dieser schädlichen Gase, aber auch der Sektor mit dem größten Potenzial für Verbesserungen.

Die in der modernen Welt verfügbare Technologie ermöglicht es, zielgerichtete Ansätze zur Reduzierung der Treibhausgase im Verkehr zu entwickeln. Die Entwicklung von Elektroautos wurde in den letzten Jahren stark vorangetrieben, gleichzeitig wird auch an Systemen geforscht, die das autonome Fahren von Autos ermöglichen. Die Bemühungen der Autohersteller sind jedoch nur der erste Schritt zu einer effizienteren Form der Mobilität. Konzepte wie Carsharing müssen gesellschaftlich akzeptiert und angenommen werden, um die Treibhausgase zu minimieren. Außerdem wird erwartet, dass durch den Einsatz autonomer Fahrzeuge die Zahl der Fahrgäste in einem einzigen Fahrzeug steigen wird, was zu weniger Fahrzeugen auf den Straßen führen würde. Die Automobilhersteller sind sehr daran interessiert, ausgeklügelte Unterhaltungssysteme zu entwickeln, um Langstreckenfahrten für die Fahrgäste angenehmer zu gestalten.

Ziel dieses Forschungsprojekts ist es, einen Prototyp eines Multiplayer-Spiels mit geteilten Rollen für mobile Plattformen (z. B. Android Smartphones oder Tablets) zu entwickeln, um zu untersuchen, welche Auswirkungen eine solche Lösung in einem autonomen Fahrzeug in Bezug auf Unterhaltung und Benutzerfreundlichkeit haben kann. Konkret soll diese Prototypstudie herausfinden, ob solche Anwendungen traditionelle Unterhaltungssysteme im Auto, wie z.B. integrierte Bildschirme in den Kopfstützen, ersetzen können.

Abstract

Mobility is an indispensable part of daily life. Whether in rural or urban areas, many people rely on public transport or cars to get from one place to another. Especially in rural areas, the use of cars can hardly be avoided, as the public infrastructures in many countries are not developed well enough to enable climate-friendly long-distance travel. As a result, the number of passenger cars in the European Union has risen steadily over the last 10 years. The main problem of this development is the emission of greenhouse gases. The transport sector is one of the biggest emitters of these harmful gases, but it is also the sector with much potential for improvement.

The technology available in the modern world makes it possible to develop target-oriented approaches for reducing greenhouse gases in transport. The development of electric cars has been greatly advanced in recent years, and at the same time research is also being carried out on systems that enable autonomous driving of cars. However, the efforts of car manufacturers are only the first step towards a more efficient form of mobility. Concepts such as car sharing must be socially accepted and embraced in order to minimise greenhouse gases. In addition, it is expected that the use of autonomous vehicles will increase the number of passengers in a single vehicle, which would lead to fewer vehicles on the roads. Hence, car manufacturers are very keen to develop sophisticated entertainment systems to make long-distance trips more enjoyable for passengers.

The aim of this research project is to develop a multiplayer game prototype with shared roles for mobile platforms (e.g., Android smartphones or tablets) to investigate which impact such a solution can have in an autonomous vehicle when it comes to entertainment and usability. More specifically, the prototype study aims to find out whether such applications can replace traditional entertainment systems in cars, such as integrated screens in the headrests.

Contents

CHAPTER 1

Introduction

In response to the growing concern over the rise in greenhouse gas emissions from vehicles and the urgent call for innovative traffic solutions, this section outlines the foundational rationale behind this project. The objective is to delve into the potential of multiplayer games within autonomous vehicles as a novel approach to address these pressing challenges and create a more sustainable future for transportation.

1.1 Problem Definition

For decades, car traffic has been one of the world's biggest air polluters and a major contributor to accelerating climate change. In 2019, the transportation sector accounted for 12% of total greenhouse gas emissions in the European Union (EU), which is a major concern for the EU Commission in view of the EU's climate targets [1]. Missing the climate targets would lead to drastic consequences in the near future. Natural disasters, heat waves, rising sea levels and melting glaciers are just some of the devastating examples that will occur more frequently in the future if we do not reduce our emissions [2].

From a social point of view, climate change is one of the greatest challenges that humankind has ever faced. Hence, the world's alliances are striving to find solutions for a more sustainable future. A major breakthrough in international climate policy was marked by the Paris Agreement. The main goal of the agreement is to reduce global greenhouse gas emissions to zero by the middle of the 21st century in order to limit global warming to 2° Celsius compared to pre-industrial levels [3].

The current developments of technology can be used in the automotive sector to achieve drastic reductions in emissions. The production and improvement of electric vehicles (EV) has been pushed in recent years, as they are more efficient and environmentally friendly than conventional cars. Initial studies have already proven that EVs significantly reduce greenhouse gas emissions [4]. Apart from their lifespan and high maintenance costs, they

are nevertheless a good alternative for a lower-emission future. Advanced technologies, such as automated vehicles, can help to make transport even more efficient, leading to further reductions in emissions. Despite intensive research, it remains interesting to see how this field will develop. Major progress is expected by the year 2030 [5].

While it's evident that the rapid evolution of technology opens up many possibilities, it's important to acknowledge that this represents just the initial stride towards achieving efficient road transport. There will have to be a collective rethinking in society in order to optimise the use of technology. This refers to individual consumption patterns that lead to higher greenhouse gas emissions. The task is to adapt personal behaviour in order to save the world's climate. To advance towards a more sustainable future, minimizing short car trips whenever possible and maximizing the number of passengers during long-distance journeys is a prudent approach. This empowers society collectively to address pressing environmental issues. Moreover, envision a future where the next generation takes the wheel, learning from eco-conscious decisions made today. By making responsible choices, a cleaner, more sustainable world is inspired for all.

1.2 Motivation

This work is closely linked to the curriculum of the study program *Media and Human-Centered Computing*, specifically to the courses Foundations of *Ubiquitous Computing and IoT* and *Building Interaction Interfaces*, which have contributed to its inspiration and focus. The learning content of *Foundations of Ubiquitous Computing and IoT* is to introduce students to the concept of integrating computing technology into everyday objects and environments. On the other hand, the lecture content of *Building Interaction Interfaces* focuses on the design and development of interaction interfaces in the field of human computer interaction. The learning outcomes of both courses are:

- Understanding the concept of context-aware computing and how to properly design meaningful services to users.
- Design and implementation of applications which use sensors for context detection.
- Design, development and evaluation of innovative interaction interfaces in the field of human computer interaction.
- Ability to apply the different phases and associated activities and methods in a user centered design process.
- Ability to apply structured methods for ideation and idea generation.
- Implementation of new and innovative interaction paradigms.

The use of entertainment systems in passenger cars is fundamentally nothing new. Traditional systems use screens integrated into the back of headrests, for example. The

problem with these systems is the high surcharge that car manufacturers charge compared to the basic equipment of their cars. Thus, in 2023, such systems will still be part of the premium equipment of a car and will remain unavailable to most car owners. Car manufacturers will increasingly integrate their entertainment systems into base models of self-driving cars to make them more attractive to the masses. Apart from traditional systems, the use of tablets, Virtual Reality (VR) or Extended Reality (XR) glasses can bring enormous benefits. On one side, fewer components are required, and these devices remain cost-effective, such as the Oculus Quest 2, which is priced at 349 Euro. Thus, new types of systems (e.g., embedded systems consisting of hardware and software that communicate with each other) will make it possible to transform the vehicle interior into a space for entertainment.

1.3 Aim of the Work

The aim of this thesis is to create and evaluate a multiplayer game for tablets in the form of a prototype. Further details about the prototype are explained in the following chapters. To create a reasonable prototype, it is necessary to combine elements of the research areas human-computer interaction and game design.

Important aspects to consider are the design of the user interface of the prototype, the limited freedom of movement in the car and the integration of sensor data into the prototype. In order to find solutions for these aspects, it is necessary to perform a state-of-the art analysis of existing research projects. The use of VR applications in vehicles is rather limited, as the elimination of motion sickness is much more challenging compared to conventional VR applications. Therefore, the prototype will be played on tablets. The project can be adapted into a VR application at any time. However, this step is left open for this project and remains open for future work. Another aspect for a useful prototype is the choice of genre, as not every genre is suitable for all age groups, and the embedding of the car movements in the game (context modelling).

The definition of roles holds significant importance in the prototype implementation, as the driver, even in the context of semi or highly automated vehicles, must remain attentive to occasional interventions in vehicle controls and cannot always fully engage in the game. At the end of this thesis, the collected information shall answer the following research question:

- **What features and elements should be incorporated into an in-vehicle multiplayer game to encourage carpooling with shared roles among players?**

All of these requirements are addressed in the context of automated vehicles. This thesis will use an exploratory approach to answer whether the use of multiplayer applications in vehicles is of relevance and to what extent different platforms like tablets, VR or XR can be meaningfully used as entertainment systems in vehicles.

1.4 Structure of the Work

This thesis attempts to gain insights into a broad field of research. The high availability of smartphones now makes it possible for everyone to play games during long car trips. Nevertheless, it is not clear how to create a comprehensive system in which the data of the self-driving vehicle can be incorporated into an app.

Chapter 2 introduces basic concepts and terminology from the research fields of in-vehicle gaming and examines how such applications have been used in vehicles so far. as the research field around in-vehicle gaming and multiplayer gaming in relation to autonomous cars is still relatively young, not only applications for tablets will be considered. With embedded systems, it will also be possible to play VR and XR applications in the vehicle, thus these platforms will also be considered in the second chapter.

Building on the basic concepts from the previous chapter, chapter 3 explains the design of the prototype in more detail. The prototyping is divided into two phases: low-fidelity and high-fidelity prototyping. In a first design, which contains less details, the features, roles of the players, interactivity elements and the overall structure of the prototype are assessed. In a revised prototype, details and more features are added. This design approach allows to test the user experience, features and interactivity in the game.

Chapter 4 deals with the implementation of the prototype. Basic concepts for the development multiplayer applications and frameworks used in the development are presented. The hardware used in this project is discussed as well.

Chapter 5 presents the results of the evaluation of the prototype. A combination of two research approaches, namely qualitative and quantitative research, provides information about the research problem. The finished prototypes will be tested by a group of users. The first prototype is tested under real-world conditions in a car and the second prototype is tested in an experimental testing session in the laboratory. After extensive testing, the participants will fill out a questionnaire and in addition there will be interviews to evaluate the user experience of the prototype.

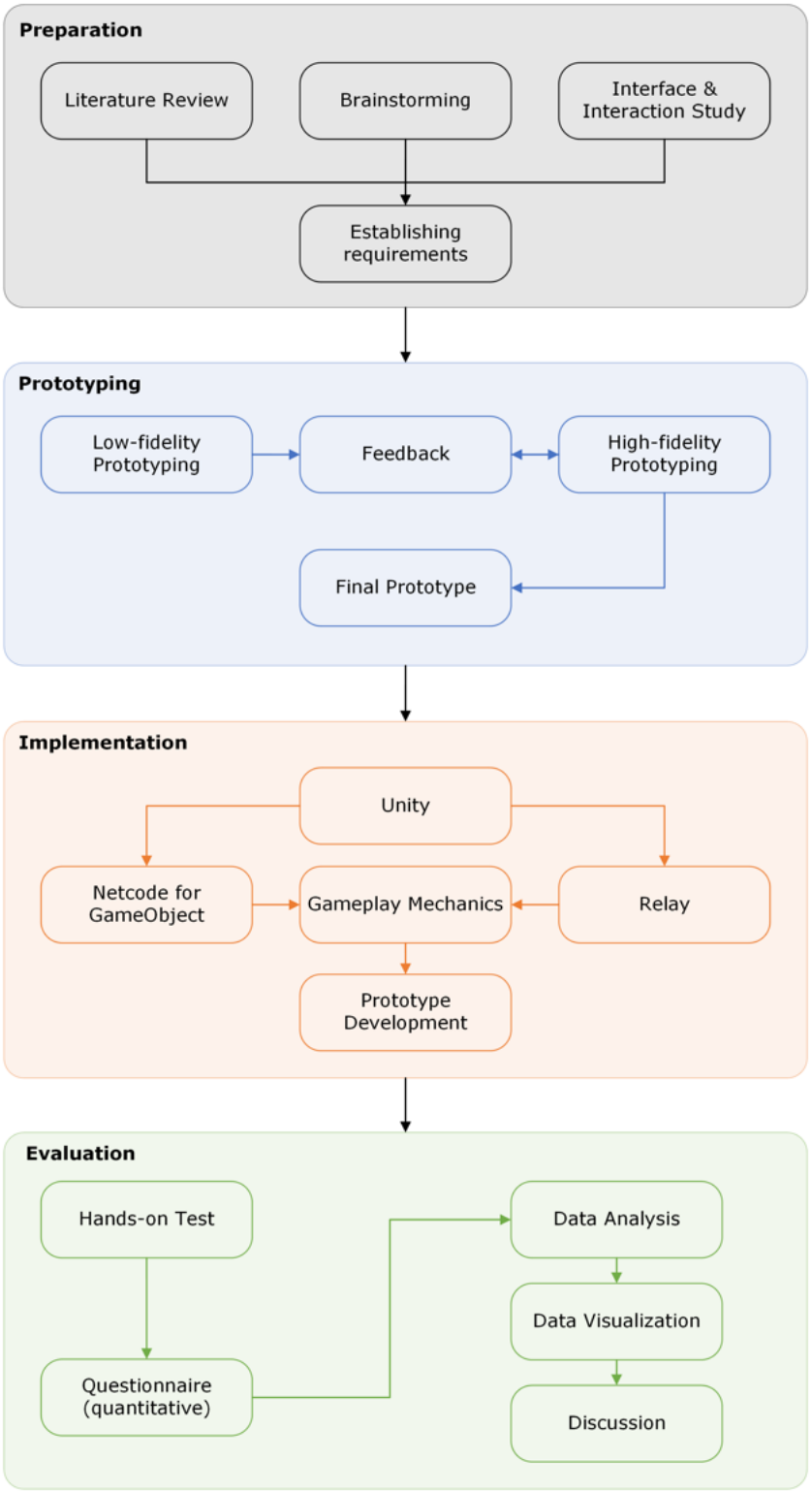

Figure 1.1: Methodological framework employed in this thesis to address the research question, encompassing a four-step process.

CHAPTER 2

Related Work

This chapter deals with the theory and concepts of in-vehicle gaming in depth. In addition to important concepts, related scientific work is analyzed. The analysis is intended to provide information on which design approaches can be considered for multiplayer applications in vehicles and how a reasonable system design can look like.

2.1 Terminology and Key Concepts

2.1.1 Infotainment Systems in Vehicles

In recent years, infotainment systems have taken on a significant role in modern vehicles and are now considered an integral part of them. The functionalities of these systems are achieved through a combination of information and entertainment functions that enhance the comfort, entertainment and connectivity of the driver and passengers. Apart from the central feature of an infotainment system - the navigation system - multimedia playback is another important component of such a system. Various controls and user interfaces allow easy access to the entertainment functions [5]. Embedded touchscreens on the back of the headrests allow rear-seat passengers to access various entertainment functions. The design of the user interface should be kept relatively simple to avoid distraction or frustration for passengers, even if the system is embedded in a self-driving vehicle [6]. Especially on long journeys or when travelling with children, infotainment systems can be used to create a more pleasant travel experience.

Going one step further and combining advanced information technologies, communication systems and vehicle sensors, a holistic system is created in which every component of a vehicle communicates with each other to enhance passenger safety and entertainment. This results in a large sensor network. The data of an Intelligent Transportation System (ITS) can be read out in real time and used for various functions such as safety-related assistance systems or entertainment applications. Although the main goal of an ITS is

not primarily the entertainment of passengers, such systems can still be used to improve the development of entertainment applications [7].

2.1.2 In-Vehicle Games

In principle, any kind of mobile game can be played in a vehicle. However, with infotainment systems in combination with ITS, special applications can be developed that provide an entertaining option for the passengers of a vehicle. These applications are characterised by their adaptation to the vehicle environment and the needs of the passengers. the integration of external systems and the use of sensor data from the vehicle play an important role in meeting the requirements of a meaningful application [8]. The vehicle's data, such as acceleration or braking forces, can be used in a game to trigger certain actions. This is a certain challenge, especially for the development of a prototype, as no real-time data is available during development. However, it is possible to simulate such data using the built-in accelerometer of a tablet or smartphone [9]. The development of rear seat games with real data from the onboard diagnostic module (OBD) has already been implemented in some projects and provides useful results for further research. Wilfinger et al. [10] developed a toolkit that combines real-time smartphone data and OBD data to provide meaningful data sets for various applications [10]. For such applications, suitable hardware like micro-controllers and OBD adapters is needed to read the data. Furthermore, the data must be processed and converted into a suitable format in order to be used in a meaningful way.

Multiplayer experiences allow the participants to play a game together or against each other. When designing such a game, it is important to ensure that the interactions are relatively straightforward. Depending on the genre and the target group, various factors must be taken into account when developing such applications. Tests have shown that cooperative and collaborative games are suitable for use in vehicles [11]. Furthermore, the network components in games are important, as in multiplayer games the connectivity to the server must be guaranteed at all times in order to keep the user experience at a consistently high level. Adaptable client-server architectures can be particularly helpful in this regard [12]. Networked systems, which are available in the case of self-driving vehicles, make it possible to develop creative applications that can also be played across vehicles, for example on a busy road or motorway. An example of cross-car, multiplayer games could be a co-op game where the occupants have to work together as a team to achieve certain goals. For example, they could work together to solve puzzles, overcome obstacles or complete missions. Players can take advantage of semi-autonomous vehicle technology to focus on the game while the vehicle takes over the driving tasks. However, the design and development of such applications is much more complex than traditional multiplayer games [13].

2.2 Virtual and Augmented Reality In-Vehicle Gaming

The use of VR in vehicles has only been sparsely researched in comparison to its conventional use in the entertainment sector [14]. Only in the last few years efforts have been made to address the topic in order to create new, future-oriented solutions for entertainment in a vehicle. In this respect, it remains to be seen how the field of research on autonomous driving vehicles will develop. Much of the existing scientific work is focused on the use of VR for passengers in the vehicle and not for the driver, as the use of VR HMDs while driving can be dangerous.

The first commercial platform for in-vehicle VR applications comes from Holoride, a company founded by Audi Electronics Venture. The applications are specifically designed for use in vehicles and use the movements of the vehicle to adapt the VR content in the virtual world [15]. The problem with commercial applications is that the technical aspects remain a secret to the public, which in turn dampens the further development of such systems. For in-vehicle VR applications, this is one of the most challenging tasks to overcome in the development, as one has to match the movements of the vehicle with the movements of the virtual world to alleviate motion sickness. The OBD module in a car, which stores and processes important key data and measurements of a vehicle, can be used to accurately transfer physical forces to an VR application [16]. Matching the movements of the vehicle with the movements in the virtual environment can be done in different ways. Cho et al. implemented this, for example, in the form of transparent walls or particle flows in the virtual environment [17]]

The choice of genre for the prototype depends heavily on whether it is suitable for in-vehicle gaming or not. Among the genres that have been evaluated in various studies are platform games, puzzle games and open word games. They have all proven to be promising genres for in-vehicle VR games [18]. Among the genres that should be avoided is the "horror" genre. Chatta et al. reported a significant difference in motion sickness in the genres "pleasant" and "horror" [19].

Multiplayer games can be implemented in different ways. On the one hand there are collaborative games and on the other hand competitive games. In principle, it is important to create a harmonic environment in the vehicle in which the players feel comfortable. The approach of cooperative games could lead to the opposite. It has been shown that card games, for example, which can be played together, promote collaboration between the players, which in turn leads to a more pleasant ride for all passengers [16].

CHAPTER 3

Methods

The methods section of this thesis serves as a critical component in the research process, offering a detailed account of how the study was conducted, data were collected, and analyses were performed. It provides transparency and clarity, enabling readers to evaluate the accuracy and validity of the research. The emphasis on a clear and structured methodology underlines the integrity of the research process, contributing to the credibility of the study's results and conclusions.

3.1 Participants

A total of 14 participants completed the study. Out of the 14 participants, 9 were male and 5 were female. Thus, male participants make up the numerical majority in the sample. The participants were primarily recruited from pre-existing networks of friends and acquaintances. This approach was chosen for its practicality and accessibility, allowing for the inclusion of a diverse group of individuals who were willing to participate in the research. Potential participants were approached with an explanation of the study's nature and purpose, and those who expressed interest were invited to take part. This method ensured a level of comfort and familiarity among participants, which can be advantageous in small-scale studies where interpersonal dynamics are relevant.

3.2 Materials

In the pursuit of the research objectives, a variety of materials were utilized to facilitate data collection, analysis, and experimentation. This section provides an overview of the key materials employed throughout the study.

Questionnaires play a crucial role in prototype testing as they collect valuable information from the study participants and allow for a deeper understanding of the user's perspective.

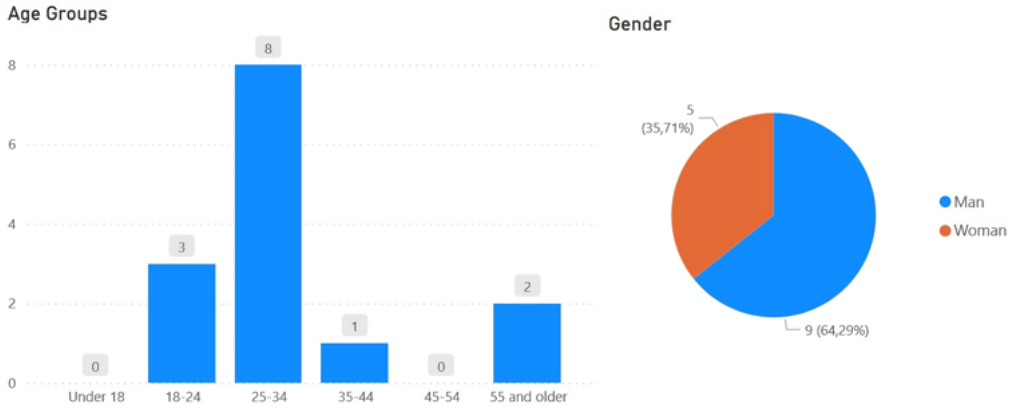

Figure 3.1: Age and gender distribution among the study participants.

The prototype testing phase is about evaluating a new product, application or service before it is fully developed or implemented. A major advantage of questionnaires is their standardisation, which allows for comparability of data. By having all participants answer the same questions, a uniform basis is created to analyse the results.

This contributes to the objectivity and reliability of the data collected. Another important aspect of questionnaires is their efficiency. This saves time and costs compared to other data collection methods such as interviews or focus groups. Questionnaires also provide anonymity and privacy for participants. Personal information does not have to be revealed in the questionnaire to ensure honest feedback. This encourages openness among participants and allows them to express their opinions without bias.

After the 25 minute test session, the participants were asked to answer a questionnaire consisting of 32 questions. The questionnaire was divided into 6 different categories:

- Demographic Information
- Gaming Experience
- Safety and Comfort
- Visual and Audio
- Economical and Social Factors
- Safety and Comfort
- Additional Comments

A total of 7 questions are designed to provide insights into the thoughts of the participants in order to assess whether multiplayer games in vehicles can maximise passengers and possibly encourage the use of services such as carpooling or ride-sharing. All questions of

the six different categories can be found in the appendix. The questionnaire was created with "Microsoft Forms". Various software tools were utilized for data analysis, including statistical analysis software "R Studio" and "Power BI" as a visualization tool. These applications were essential in processing and interpreting the collected data.

3.3 Procedure

The experimental setup for playtesting in the vehicle was carefully chosen to allow the test subjects in the back seat to test a game prototype for 25 minutes each. A suitable vehicle was chosen that offered a safe and comfortable back seat and sufficient space for the participants. Particular attention was paid to ensure that the vehicle was in perfect technical condition to ensure safety during the test drives. The prototype to be tested was installed on a tablet (Samsung Galaxy Tab S3) and a smartphone (Samsung Galaxy S21 FE), which were held by the test persons on the back seat. An example of the test setup can be seen in Figure 5.1. This gave the test subjects a comfortable and easily accessible position to operate the game while driving.

The safety of the test subjects was the top priority. All participants were asked to buckle up and use their seat belts properly throughout the test drive. In addition, an observer or assistant was called in to accompany the test subjects during the drive to monitor compliance with the safety measures and to react immediately if necessary. A predefined test route was chosen to cover different driving situations, such as city traffic and country roads. This allowed different aspects of the game to be tested under different conditions.

The test subjects were given clear tasks and encouraged to test the game in detail while driving. They were asked to explore different features of the game and evaluate the game experience. Aspects such as usability, controls, graphics, game concept and possible distractions were taken into account. The tests were repeated with different participants to obtain a wide range of opinions and feedback. The collected data and feedback was analysed to identify possible improvements to the game and to optimise the gaming experience. The experimental setup was carefully planned to create a realistic and safe test environment for the prototype. The findings from this trial setup will be used to optimise the game for in-vehicle use and provide an entertaining, yet safe gaming experience.

The 25 minutes per session result from the following tests:

- **Test 1:** 5 minutes singleplayer without any other features like multiplayer or accelerometer.
- **Test 2:** 2 x 5 minutes singleplayer + accelerometer (both levels: rotation and shifting)
- **Test 3:** 2 x 5 minutes multiplayer + accelerometer (both levels: rotation and shifting)

The following hypotheses were formulated for the statistical tests.

Null hypothesis (H0): The absence of specific features, such as the projected movement context and multiplayer features, does not result in a less favorable rating compared to the game with those features included.

Alternative hypothesis (H1): Introducing movement context and multiplayer features into the game will lead to significantly higher ratings compared to the plain game without these features.

Figure 3.2: Experimental Configuration - Two Participants engaging in a 25-Minute game test.

CHAPTER 4

Conceptualizing a Match-Three Puzzle Game for In-Vehicle Entertainment

This chapter is dedicated to exploring the fundamental ideas and principles that underlie the development of the game prototype. In this chapter, the conceptual framework driving the design and creation of the prototype is examined, incorporating essential concepts, theories, and design considerations.

4.1 Game Prototyping

Game prototyping serves the purpose of testing and evaluating a game concept before investing numerous resources in production. There are some factors - especially in game development - that need to be considered when prototyping a game, such as the concepts explained in the previous chapter like the integration of the game in the ITS, interactions and usability. These concepts play an important role and need to be addressed accordingly in order to design a mature prototype that can be tested by users. The goal of the prototype is to visualise the elaborated game idea. In principle, a prototype is part of an iterative game development process in which several features are added to the game after each cycle [20].

There will be a total of two iterations. In the first iteration, the key features are implemented and the focus lies on the game's core idea. In this iteration, little emphasis will be placed on the visual presentation, such as animations and effects. These will be added in a further iteration after the outcome from the first round has been analyzed. Furthermore, the second iteration should focus on the user experience, as it is important

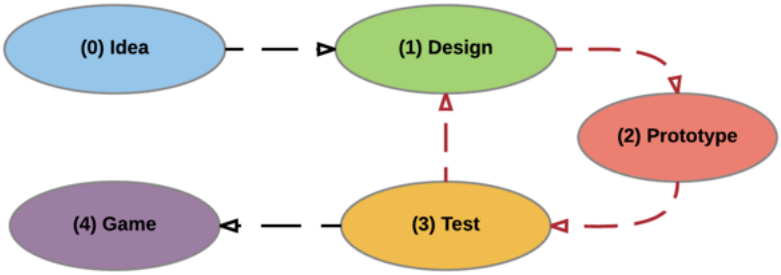

Figure 4.1: Iterative game development process used in traditional game development.[20].

to design the game in such a way that it is easy to use and intuitive for the users who test the final prototype.

4.2 Game Idea

The idea is to develop a prototype for a competitive "match-three puzzle" game in which players can compete against each other. Fundamentally, a genre is defined by certain game mechanics and actions that players can perform [21]. "Match-three games" are characterised by matching three or more similar objects in a vertical or horizontal row on the board, scoring points with each match. The number of points scored per match depends on the size of the match. For example, a match of size 4 scores more points than a match of size 3, and so on. The aim of the game is to score more points than the opponent at the end of a round. Furthermore, the idea builds on the findings of other work in this field, as the genre belongs to the overarching genre of pleasant games, in which far less motion sickness has been reported among players compared to horror games in case the prototype gets ported to the VR platform [19].

Another reason for choosing this genre are findings from cognitive science. There is evidence that match-three puzzle games enhance problem-solving skills and visual pattern recognition among players [22]. Basically, there is only one specific rule, namely that only two adjacently placed objects can be swapped, which contributes to the ease of entry into this genre, as it makes the gameplay simple and intuitive. The simple gameplay also leads to instant gratification when players achieve certain goals or points to outperform their competitors.

Creating a competitive environment also leads to players developing long-term motivation and more enjoyment of the game [23]. This aspect is particularly important with regards to the economic factors of this project, as such a game helps to increase the number of passengers in a car, which in turn can lead to fewer cars on the road to reduce emissions. This in turn implies that not only one or two people sit in the car, but as many passengers as possible. In terms of freedom of movement in vehicles, 4 people in the vehicle is ideal, as otherwise there is simply too little room for using VR applications in vehicles. The limited freedom of movement in vehicles does not support the development of a room-scale

VR environment, thus a setting in which the user interacts with the virtual environment in a seated position is required. This fact has a particular impact on the perceived immersion in the virtual world. Seated VR configurations lead to less immersion, which can make the development of such applications challenging [24].

Compared to traditional match-three games, which are usually played on smartphones, some important limitations need to be considered. On the one hand, costly hardware for reading OBD data is not available for this project. This means that reading data from the OBD and sending it to the device on which the game is played to match the movements in the virtual world with those in the real world can not be implemented. Therefore, the prototype will be tested with data from the tablets accelerometer which might not replicate the data from the OBD (e.g., forces in a left or right turn). It is expected that the usability of the prototype will not be equivalent to that of a fully embedded application in a vehicle.

4.3 Game Design

The game design of a classic match-three puzzle game includes many elements. The basic element is the game board on which the tiles or gems are placed. With a size of 7 rows and 7 columns, it contains a total of 49 tiles (7x7). In principle, the board does not have to be quadratic, but can have any shape. For the prototype, however, it is simpler to make the shape of the board as basic as possible. The 49 tiles are objects that the players can move around the board. As already mentioned, only two adjacency tiles can be swapped. Three or more identical game objects make a match and disappear from the board. New tiles fall into the board from above. The tiles have different colours and shape to distinguish them. There will be a total of 5 different tiles for the prototype. The assets are available to the public without any costs in the unity asset store [25]. Red-green combinations should be avoided, as they are often indistinguishable for people with a red-green weakness [26]. An example of suitable colours and shapes can be seen in Figure 3.2.

Figure 4.2: Game tiles - also called as "Gems" in Match-Three puzzle games - used in the prototype.

4.4 Roles

One of the most important aspects of the project is the definition of the roles that the passengers of the car are assigned to. Apart from the driver, nothing special needs to be considered when defining the roles. The other three passengers - the co-driver and

Person	Role	Tasks
Driver	Game Master	The game master oversees gameplay during the contest and can activate events (e.g. randomly switch boards) without the knowledge of the participants.
Co-Driver	Competitor	Competitors try to score as many points as possible in a game round to beat their opponents.
Rear seat passenger 1		
Rear seat passenger 2		

Table 4.1: Role assignments for the prototype.

the two passengers in the back seat - do not have to intervene in the operation of the vehicle, which means that they are fully focused on the game. These three passengers share the role of the competitor and will compete against each other in the game to get the best score. The competitors have their game board with the tiles in focus and can see the (board) score of the other competitors on the user interface. It is important to ensure that certain visual effects do not distract the players. The role of the driver has to be adjusted for safety reasons. In principle, there are 5 levels (0-4) of autonomous vehicles, with level 0 corresponding to "no automation" and level 4 to "full automation" [27]. No system is 100% safe, so it must be ensured that the driver is able to intervene in an emergency, for instance to avoid an accident. Therefore, it is reasonable to give the driver the role of the game master. In this way, he can observe the game and also actively participate, for example by swapping the boards of the players. A breakdown of the roles and tasks in the game is shown in Table 3.1.

4.5 Rules

The rules of the game are kept very simple. A round consists of one or more games that are played simultaneously but independently by all players. As in classic match-three puzzle games, each player may make as many moves as the remaining time allows. The time per game can be set individually so that longer competitions can be played against each other. However, the minimum playing time per game is 5 minutes, otherwise the players have too little time to score points. Similar to Dynamic Difficulty Adjustment (DDA), which help to make games challenging, this feature is intended to make the game playable for a longer time without getting boring [28]. Players can look at the score of their opponents, but cannot trigger special events. This is left to the game master. He has the overview of the game and can switch the boards of the competitors at certain intervals. This should help to make the game more exciting. Players with a lower skill level can also compete against better players, as the chances of winning the game are evened this way. For the sake of completeness, the role of the game master is only described theoretically and not implemented in practice in order not to go beyond the scope of the prototype.

4.6 Game Mechanics

A variety of mechanics, like multiple layers on the board or non-moving obstacles, are used in match-three puzzle games to make the game more interesting and challenging [29]. The core gameplay consists of the so-called matching type, which determines how the players interact with the board. According to statistics from GameRefinery - a company that develops video games - about 60% of all match-three puzzle games use swapping as the matching type [30], i.e. moving two adjacent objects on the board. Other matching types include linking, shooting and collapse.

The second core mechanic is matching. The player must combine at least three objects of the same colour or shape to create a match, which earns the player points depending on its size. Figure 3.3 shows a game sequence of a simplified board (5x5) that illustrates both mechanics. In the first step, the player swaps two adjacent gems with each other to achieve the largest possible match. After swapping, the orange triangles create a match of size 4. These 4 game objects are then removed from the board and the empty spaces are refilled with random game pieces.

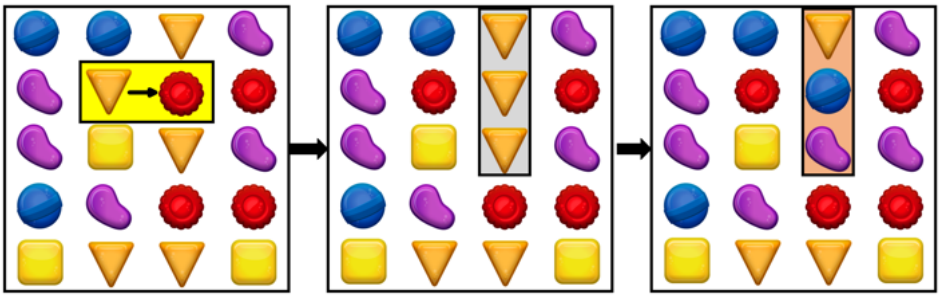

Figure 4.3: The core game mechanics: Swapping and matching.

For the prototype, it is important to focus on the core mechanics. Object swapping and matching are integrated into the game. All other features are not of interest for the prototype. Other features can be integrated later, which is not a difficult task once the core mechanics is in place. The specification for the number of certain moves is also omitted.

4.7 Context Modelling

In principle, the game can be implemented and tested with the described mechanics, but the context of the primary topic of this research - in-vehicle gaming - is lost. Therefore, it is important for the development of the prototype to model the movement context correctly, as this helps to simulate real driving conditions, which in turn leads to the prototype having the desired functions and the expected behaviour of a finished product. An implementation that does not take the context into account will result in a prototype that does not meet the needs of the specific requirement, thus losing the initially defined

selling point of the project. The correct modelling of the context will also save time and resources further down the line - if the project is pursued further - as the prototype will be of higher quality. The development of context-aware applications is a complex issue in itself, as there are many models that can be used [31].

The most important contextual information in this project is the location information of the vehicle. The modelling of this information can be implemented using different approaches. For example, the accelerometer of the tablet, which measures the linear acceleration. This makes it possible to determine which forces are affecting the tablet in a left or right turn. Additional hardware such as GPS sensors can be used to track the position of the vehicle in the virtual world to provide a dynamic experience. However, the use of additional hardware was already ruled out in advance. Thus, the modelling of the movement context is based on data from the accelerometer.

To complete the scope of the project in the given context, an experimental prototype is being developed but not tested. Sensors and camera systems in autonomous vehicles allow, for example, to feed a live camera feed into the application (e.g. the front camera is displayed as background in the game). This information can be used to reflect the movements of the vehicle into the game. The simulation of the visual adjustments to reflect the movement of the vehicle in the virtual world is implemented as follows. Players can follow the the route on a mini-map. This will give the players an overview of the simulated route and the current position of the vehicle. This should help to better anticipate the simulated movements of the vehicle in order to adjust game decisions accordingly. The mini-map can be displayed as a small window at the top or bottom of the screen. It is important that it is not distracting for the players, which would cause them to lose focus on the game board.

To embed the context of the movement into the game, it is necessary to make visual adjustments to the game board. There are several approaches to this. In the case of a left or right turn, for example, predefined columns of the game board can be shifted to the left or right or the player can select a column or row that is moved to the left or right. In order to improve the game experience and make the game more entertaining, the second approach is adopted. The players receive a message - e.g. above or below the game board - a few seconds before driving a simulated curve, which lets them select a column or row of the game board that will be shifted either to the left or to the right when driving a curve. A prerequisite for this feature is the refilling of game objects on the game board, as certain objects disappear from the game board when a column or row is moved. New objects are added to the board randomly.

Figure 3.4 shows the simulated movement of the vehicle. The players can follow the position of the vehicle on the mini-map. The arrow indicates the direction in which the vehicle is moving. Thus, it can be determined that a left turn is approaching, which is also indicated by the message above the game board. In this case, the best option is to select line 4 (from the top), as a match of 3 purple game objects is scored after the shift. A random game piece is pushed into the game board from the right.

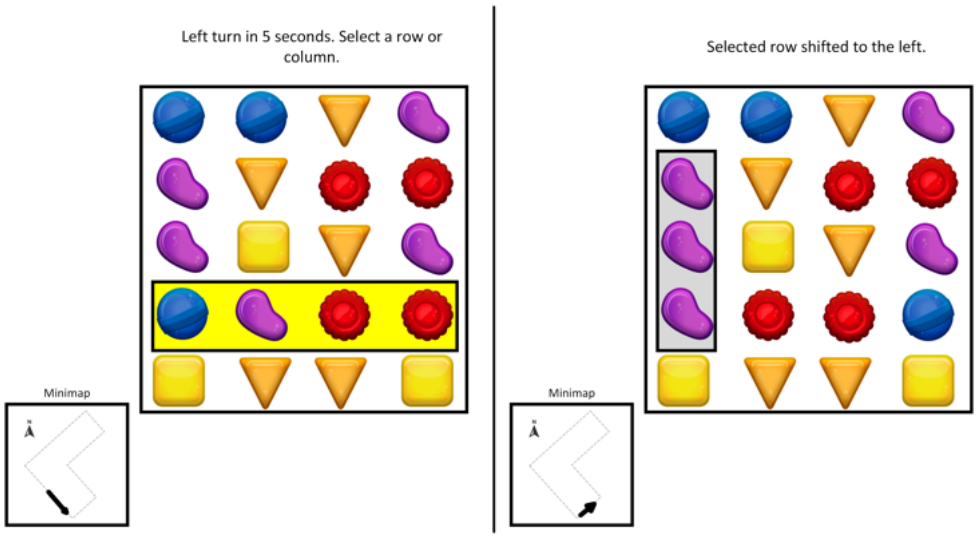

Figure 4.4: Embedding the movement context into the game.

4.8 Level Design

The level design should provide a challenge for the players. This means that the level of difficulty increases at certain intervals or after certain goals have been achieved. This can happen, for example, through the game mechanics described (power-ups, obstacles, etc.). The shape and size of the game board can also vary to make matches more difficult to achieve. It is important that the level design is balanced so that the learning curve of the players is not affected or weakened. Meaning, the players should be at the centre of the development of a match-three puzzle game.

The game board for the prototype will have only one layer and contains a total of 49 objects with 7 rows and 7 columns. Thus, the objects will be arranged in a grid-based manner. The size and shape of the board will always remain the same. There will be no special symbols or power-ups, only the aforementioned game pieces from this chapter. Fundamentally, there are no limits to how levels can be designed. There are creative solutions to randomise the level design. With generic algorithms, it is possible to generate levels dynamically [32], which in turn leads to more variety. However, the integration of such algorithms is not the aim of this project.

CHAPTER 5

Implementation

Building on the development approach described in the previous chapter, this chapter describes the development of the prototypes. In the first iteration, a prototype with the most basic functionalities - swiping, matching, score and time - is implemented. In order to not slow down the development cycle and to be as efficient as possible, the prototype of the first iteration will run on the windows platform. Based on the first prototype, the application will then be ported to the Android platform and further functionalities will be added. In the second iteration, the experimental prototype with the simulated camera feed is developed.

5.1 Iteration 1: Windows application

The decision to develop the first prototype for the windows platform has several reasons. One of the most important ones is the reduction of complexity and the simplified debugging. Compared to android applications for tablets, far fewer frameworks and assets are needed for the development. This approach allows to test and refine basic game mechanics and the level design of the game without having to enter the complex development domain of the Android platform.

5.1.1 Assets

In order to make the virtual world or the scene beautiful, various assets are needed. In principle, assets can be designed by the developer, whereby a large number of asset packages are freely available in the unity asset store, which in turn saves time. For the gems, the aforementioned asset package from the unity asset store was used [25]. It contains gems of various colours and shapes, each pre-configured with a 2D texture. These can be managed and used in Unity in the form of prefabs and prefab variants, so that changes are uniformly visible on all gems. The use of prefabs saves the time and

effort of configuring each gem individually. This is especially helpful when instantiating gems on the game board. The animations as well as particles and effects of the game to create movements and transitions were created with the built-in functionalities of unity itself. Another important part of the prototype are audio effects. These are needed for the interactions and the auditory highlighting of matches. Furthermore, a music track was used as background music to give the game a relaxing character, which is quite common for match-three games. The files for the sound effects and the music were also downloaded from the Unity asset store [33].

5.1.2 Laying out the game board

The basis of the game is the board with a total of 7 rows and 7 columns. The number of rows and columns can be configured using parameters. A prefab was created for the individual tiles, in which the gems are then spawned. The board in Figure 4.1 is therefore a two-dimensional array, starting with the position (x,y)=(0,0) in the lower left corner of the board.

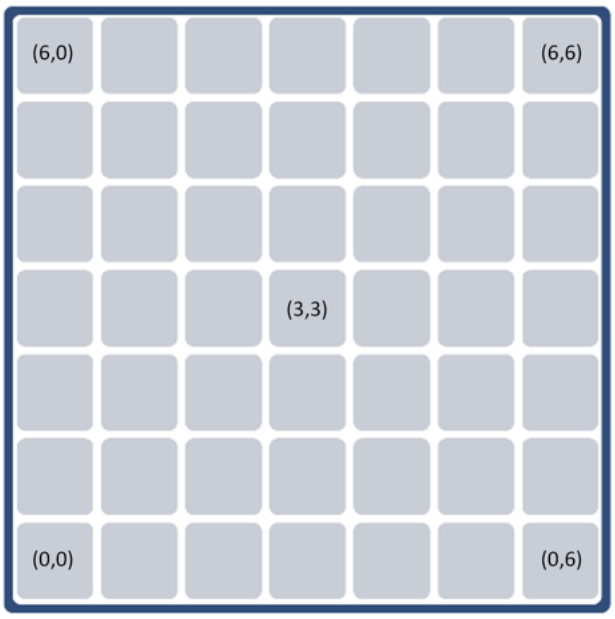

Figure 5.1: Game board with 49 tiles which serve as placeholders for the gems.

This data structure makes it relatively easy to instantiate the tiles. A nested for-loop can be used to loop over the entire board to instantiate a tile at each position. The data structure also makes it easy for other functionalities of the game. For example, finding matches can be easily implemented using a two-dimensional array. The following code snippet instantiates a tile at each position. The result can be seen in Figure 4.1. This creates the basis for the game. The next step is to fill the individual tiles with different gems.

```
private void Setup()
    {
        // Instantiate a tile on each position of the game
           board
        for(int x = 0; x < width; x++)
        {
            for(int y = 0; y < height; y++)
            {
                Vector2 pos = new Vector2(x, y);
                GameObject bgTile = Instantiate(bgTilePrefab,
                   pos, Quaternion.identity);
                bgTile.transform.parent = transform;
                bgTile.name = "BG Tile - " + x + ", " + y;
            }
        }
    }
```

5.1.3 Adding gems to the game board

Prefabs of all gem variants are needed to instantiate the gems. These can be stored in a public array, which can be populated in the Unity Editor. For spawning the gems, only the position and the gem to be spawned are required. The gems are selected randomly. In order to avoid matches at the beginning of the game, as these would score points, logical tests can be used. Here too, the two-dimensional board array is very helpful, as it can be checked immediately whether 3 or more gems of the same type have been spawned horizontally or vertically. The following code snippet randomly instantiates the gems on the board. The instantiated gem is stored in an array, which is then used to find matches and manage gems on the board.

```
private void SpawnGem(Vector2Int pos, Gem gemToSpawn)
    {
        Gem gem = Instantiate(gemToSpawn, new Vector3(pos.x,
           pos.y + height, 0), Quaternion.identity);
        gem.transform.parent = transform;
        gem.name = "Gem - " + pos.x + ", " + pos.y;
        allGems[pos.x, pos.y] = gem;

        gem.SetupGem(pos, this);
    }
```

The instantiated game board with the gems can be seen in figure 4.2. The next step is to implement the core mechanics - swapping and matching.

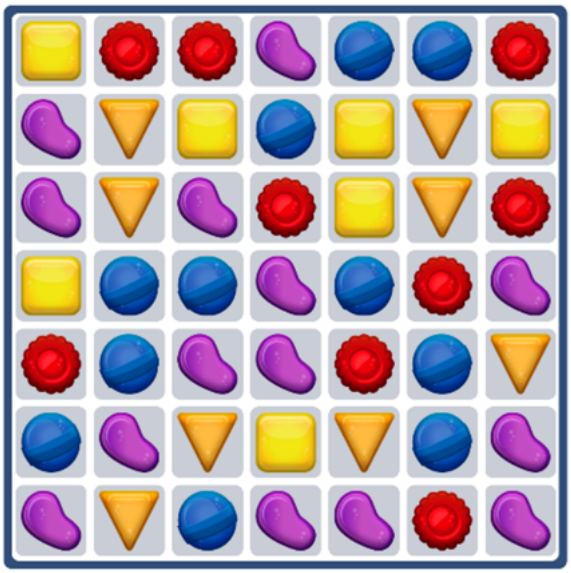

Figure 5.2: Game board filled with 49 gems.

5.1.4 Core mechanics

The most important mechanic in the game is the swapping of two adjacent gems - also called swiping. There are a few things to consider in order to implement this feature in a user-friendly way. The player should not be able to move gems out of the board. This means that gems on the edge of the board can only be swiped in certain directions. The determination of the direction of the swipe can be implemented with mathematical functions such as angles. Figure 4.3 shows an example of a gem that can be moved right, upwards, left and downwards. The angle is calculated from the position at which the gem was selected and the position at which the gem was released. To give the user some flexibility, it can be assumed that, for example, a swipe between -45 degrees and 45 degrees can be interpreted as a swipe in the direction to the right. In this way, it can be prevented that the user has to swipe exactly to the right. This makes the game experience better and user input a little easier. The same procedure can be repeated with the other directions. Thus, the user always has a 90 degree margin for a swipe in a certain direction.

One thing to be aware of is that a gem cannot be moved to the left if it is on the left edge of the board. This can be checked by additional logic queries based on the position of the gem on the board. Another mathematical function used for swiping is linear interpolation (Lerp). This function can be used to create a smooth movement of the gems so that they do not change position erratically. Thus, a gem will glide smoothly from one position to another, resulting in a much nicer visual effect. After successfully swapping two gems, only the global indices need to be changed. An example of how this logic was implemented can be seen in the following code section.

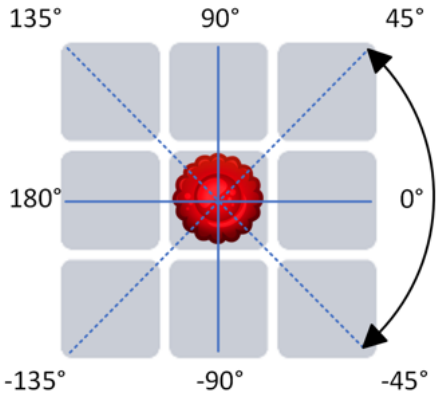

Figure 5.3: Determining the swipe direction of the user input.

```
private void MoveGems()
    {
        previousPos = posIndex;

        // Swipe to the right. Consider the border cases (gems
           on the right border of the board)
        if (swipeAngle < 45 && swipeAngle > -45 && posIndex.x
           < board.width - 1)
        {
            otherGem = board.allGems[posIndex.x + 1,
               posIndex.y];
            otherGem.posIndex.x--;
            posIndex.x++;
        }
        // Swipe upwards. Consider the border cases (gems on
           the top border of the board)
        else if (swipeAngle > 45 && swipeAngle <= 135 &&
           posIndex.y < board.height - 1)
        {
            otherGem = board.allGems[posIndex.x, posIndex.y +
               1];
            otherGem.posIndex.y--;
            posIndex.y++;
        }
        // Swipe downwards. Consider the border cases (gems on
           the bottom border of the board)
        else if (swipeAngle < -45 && swipeAngle >= -135 &&
           posIndex.y > 0)
```

```
        {
            otherGem = board.allGems[posIndex.x, posIndex.y -
                1];
            otherGem.posIndex.y++;
            posIndex.y--;
        }
        // Swipe to the left. Consider the border cases (gems
            on the left border of the board)
        else if (swipeAngle > 135 || swipeAngle < -135 &&
            posIndex.x > 0)
        {
            otherGem = board.allGems[posIndex.x - 1,
                posIndex.y];
            otherGem.posIndex.x++;
            posIndex.x--;
        }

        board.allGems[posIndex.x, posIndex.y] = this;
        board.allGems[otherGem.posIndex.x,
            otherGem.posIndex.y] = otherGem;
    }
```

The second core functionality of the game is finding matches. This can be implemented with a type label attached to gems. After each move, a check is made to see if there are 3 or more of the same gems horizontally or vertically aligned. At the position of each gems, the horizontal and vertical neighbours are looked at and checked if they have the same type (blue, orange, red, purple, yellow). If matches are found, the affected gems are marked with a flag and saved in a list. Then the matched gems are removed from the board with a particle effect and new random gems are pushed into the board from above. An example of a match sequence is shown in Figure 4.4.

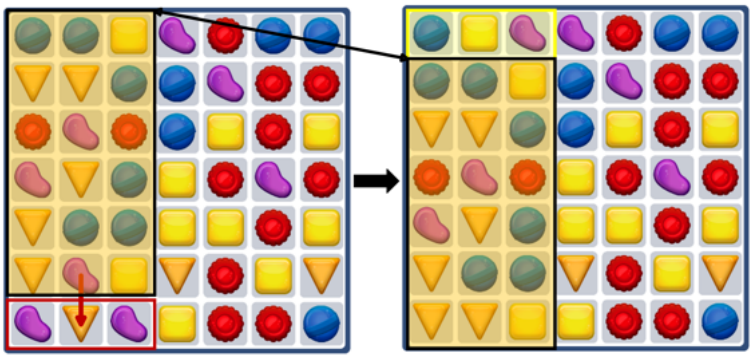

Figure 5.4: Matching of gems and random refilling of the board.

5.1.5 Time tracking and score

As already described, the play time can be configured via a parameter. For the prototype, the playing time was set to 5 minutes, as this gives the players enough time to score matches. For the high score, a simple logic is implemented. Each gem has a default value of 10 when matched and removed from the board. To reward players for good swaps, a multiplier is introduced for multiple matches in one turn. The bonus for multiple matches in one turn is half the score of the sum of the scores of the matches. The time and score will be displayed next to the board in a UI element. All elements of the UI are maintained and updated via a separate script (UI manager). A draft of the UI can be seen in figure 4.5.

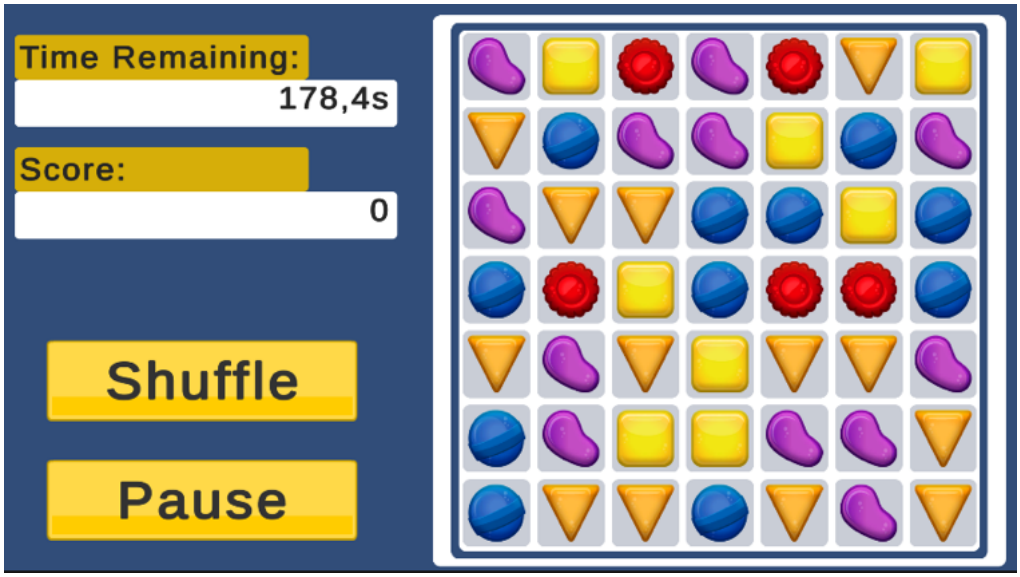

Figure 5.5: UI of the 2D Windows Prototype.

5.1.6 Random events

A very popular feature in match-three games is the use of boosters or gems with special effects. These elements are used to bring a little excitement into the gameplay and to make the game as entertaining as possible. In order not to go beyond the scope of the game, bombs were implemented that are activated when a match is scored adjacent to them. This is relatively easy to implement, as a bomb has the same functions and types as a gem and only needs to be assigned to a new label ("bomb"). The bomb then destroys all directly adjacent gems. As a result, larger matches and more points can be scored. In the Unity Editor, it is also possible to determine the chance of a bomb being spawned. By default, it is set to 2%. An example of match including a bomb can be seen in figure 4.6.

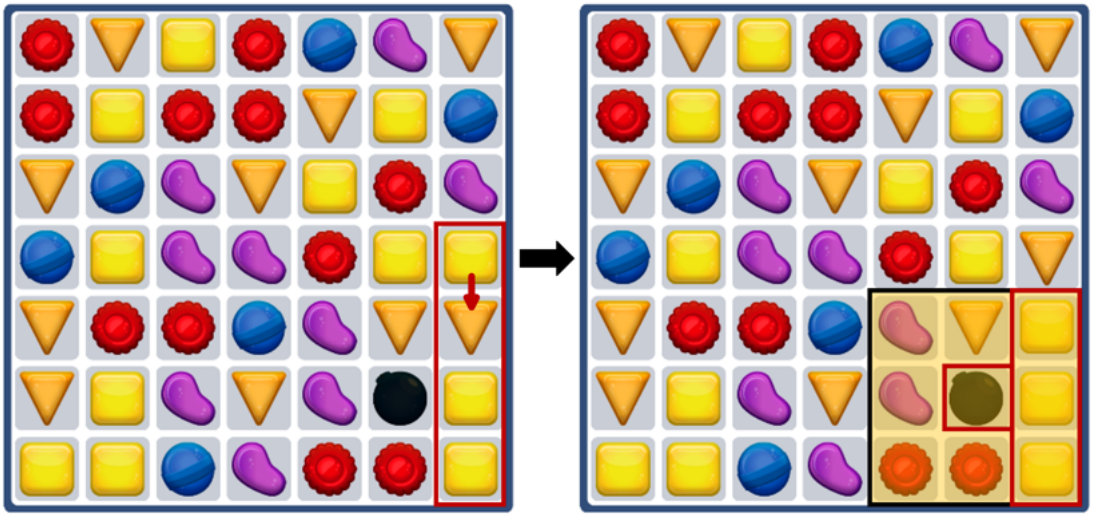

Figure 5.6: Match including a bomb which destroys all adjacent gems.

5.2 Iteration 2: Porting the Windows Prototype to the Android Platform

Building on the mechanics implemented in the first iteration, further features can now be integrated into the game. In the second iteration, the focus lies on the development of an Android application, This iteration will result in a prototypes which will be tested and evaluated afterwards. Finishing the second iteration includes the integration of accelerometer data and the integration of networking functions. The art style and visual theme of the core game will not change. This also includes the sound manager and all aspects such as the colours and shapes of the gems. After this iteration, the prototype shall have the necessary maturity to be tested by players.

5.2.1 Integrating the Movement Context

The first prototype aims to model the movement context using data from the tablets' built-in accelerometer. Although this data does not correspond exactly to the vehicle data, with this approximation realistic test conditions can be established to collect valuable feedback from the testers. Unity provides interfaces for collecting data from the accelerometer. These values are used in each frame to check whether the players are driving a curve in the vehicle. From the accelerometer data, the linear acceleration can be read in all three dimensions, although for the first prototype only the x-axis comes into question, as the tablet is either held in the hand or mounted on the back of the headrest. the mapping of the axes can be seen in figure 4.7.

There will be two different levels that look basically the same but trigger different functionality in curves. In the first level, the columns are shifted to the left in a left curve and to the right in a right curve in order to integrate the context of the vehicle movement into the game. In the second level, the whole board is rotated either 90 degrees to the left or to the right. The threshold values at which the actions are triggered are primarily dependent on the user. The mechanics for triggering the movement context can be triggered by external hand movements for example. The extent to which this affects the user experience will be discovered in the test phase.

The user interface is designed to be as simple as possible and, as in the windows prototype, consists of the board, which is arranged centrally, and UI elements that provide information about the gameplay. The arrangement of the elements has been slightly adjusted to make the layout compatible with common tablet screen sizes. Furthermore, two placeholders are added, which display the score of the player and the score of the opponent. Text fields which display information of the accelerometer data are placed on the right side below the scores, but this is less relevant for the users. The UI can be seen in figure 4.8.

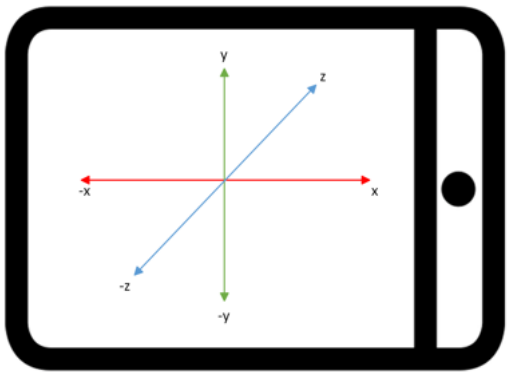

Figure 5.7: The accelerometer makes it possible to get values for the linear acceleration.

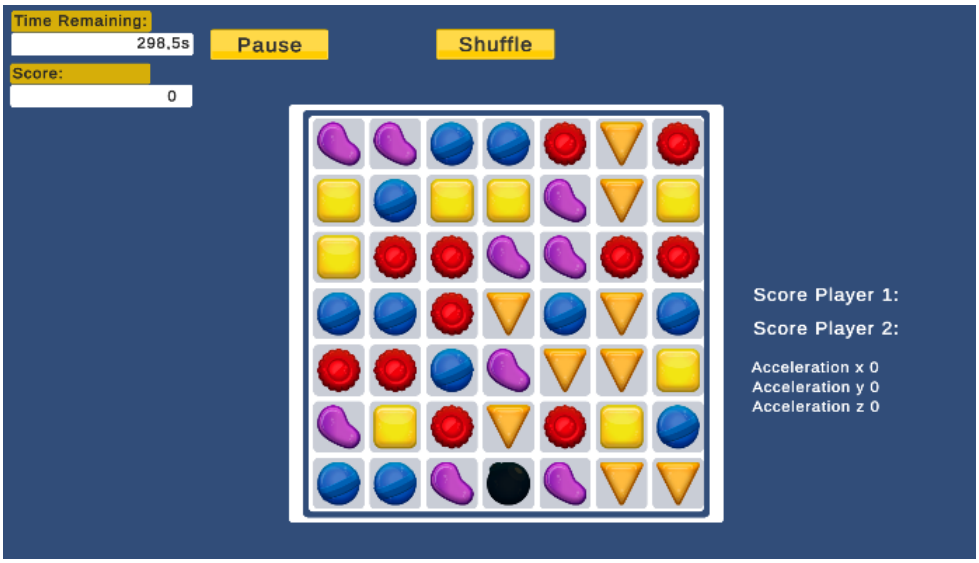

Figure 5.8: The UI of the finished prototype which will be evaluated in a car.

5.2.2 Networking

Network functionality plays a crucial role in multiplayer games, allowing players to interact with each other and play in real time. The integration of network frameworks, such as "Netcode for GameObjects" (NGO) in Unity, is crucial to ensure a smooth and synchronised gaming experience.

NGO integration starts with the identification of the relevant GameObjects to be synchronised between players. These GameObjects must be equipped with the appropriate network components to transmit their data over the network. Unity offers various approaches for this, including the use of authoritative server-client architectures or peer-to-peer connections. Using client and server remote procedure calls (RPC), data can be

sent from the server to the clients or from the clients to the server. Only three variables need to be synchronised over the network: The score, the remaining time and a true-false flag indicating whether the round has ended. These variables are declared as network variables and are automatically synchronised over the network. A network manager is also required in which the protocol type used for the exchange of data is specified. To enable smooth gameplay, it is recommended to configure the protocol type as "Relay Unity Transport". Unity Relay is a feature of Unity Multiplayer designed specifically for network communication in multiplayer games. It is a cloud-based network service that allows multiplayer games to be hosted and connected over the internet. Relay acts as an intermediary between players to facilitate communication between them. When a game is hosted through Unity Relay, players connect to Unity servers and exchange their data through these servers. This also handles the task of network address translation (NAT-T) and helps overcome problems that might normally occur when players play behind different types of network setups, firewalls or NAT routers.

The process of a creating and joining a multiplayer session works as follows. The session is started via the UI button "Host Session". In the background, allocation is created on the Unity servers. This allocation contains a join code for the session. The clients - i.e. the players competing against each other - enter the join code in a text field and join the session via the "Join Session" button. The game can then be started and the network variables are automatically synchronised. The UI elements for the network functionalities can be seen in figure 4.9.

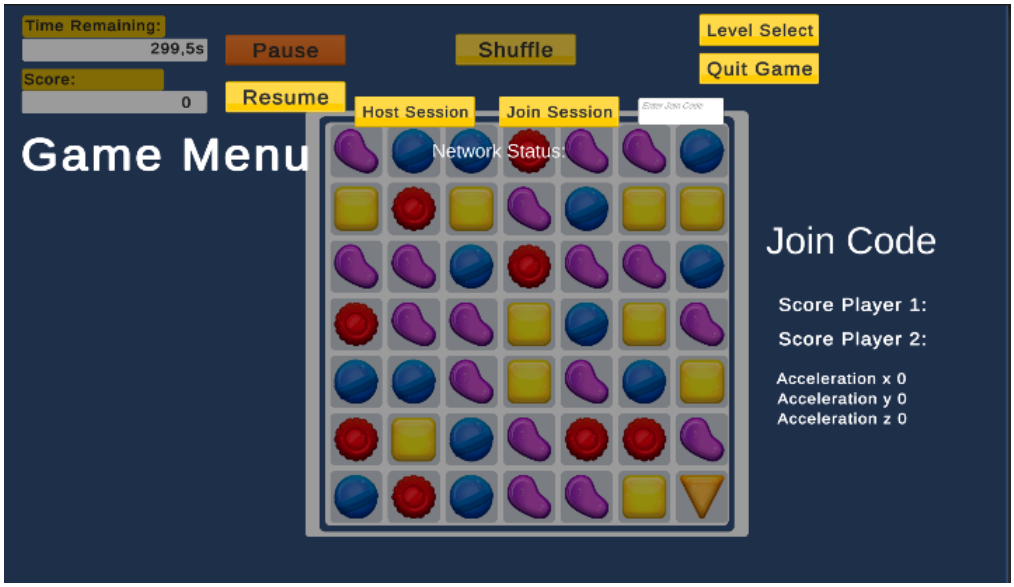

Figure 5.9: UI elements for the networking part.

5.3 Experimental Prototype: Simulated Movement Context

As already mentioned, it is possible to embed sensors and camera systems into the game. Let's say the vehicle offers the possibility to access data from a front camera. This live feed is projected in the game and the users can follow the position of the car. With this visual information together with data from the accelerometers of a vehicle, rotating the board or moving the columns can be implemented to integrate the movement context into the game. This behaviour can also be simulated. In the following subchapters, an experimental approach is pursued to simulate the movement context. However, this prototype is not tested and is only intended to show the extent to which the context can be simulated.

5.3.1 World Design

The starting point of the second iteration is the creation of a 3D world in which the game takes place. The idea is that the players are placed on a cart and follow a predefined route. This is intended to simulate real-life conditions. The idea behind this is that the game background is a live camera feed from a car's front camera. In this way, the players can follow the position of the car and certain actions are triggered in curves. The game board always remains in the centre of the screen and is therefore always in focus. With the help of simple textures and unity's built-in terrain tools, a simple terrain is created. To make the game world more vivid, trees, bushes and houses were placed at the sides of the route. Figure 4.10 and 4.11 are showing the 3D scene with the route, trees, bushes and houses.

Figure 5.10: Visual elements placed in the scene that make the game experience more lively.

Figure 5.11: The entire route with visual elements in the 3D scene.

5.3.2 Waypoint Creation

For simulating the movement of the vehicle it is necessary to implement a waypoint system so the player automatically drives the cart along the predefined route. A waypoint is game object that is placed on the route. With a suitable logic in a script, the position of the cart gets updated in each frame so it follows the waypoints along the route.

In preparation for embedding the movement context, it is necessary assign a tag to waypoints before a turn (left turn and right turn). With these tags, certain actions can be triggered in curves, which later simulate the movement context. There are a total of 204 waypoints along the route, which are placed at approximately equal intervals. more waypoints are necessary in curves so that the movement of the cart is not abrupt but smooth. A independent waypoint script serves as a component for the cart to move through the waypoints in sequence. In the update method, i.e. in each frame, the position of the cart is altered. The implemented round manager still controls the game. This means that the game is not over when the cart has completed a full lap and the set game/round time determines the end of the game.

5.3.3 Mini-Map and Movement Context

The provision of a mini-map is intended to be a handy tool to provide players with an additional source of information about the environment. It should help players to orientate themselves in the game world and to track the position of the cart. This is important as it is a supporting element for the simulation of the movement context. For the creation of the mini-map, an additional camera is necessary in the scene, which tracks the position of the cart from above. A separate render texture ensures that the recorded view of the camera can be displayed on a suitable canvas element. The mini-map is placed in the upper right corner so it does not overlap other active game elements.

As described in previous chapters, it is crucial for the prototype to include the movement context as this will lead to an immersive and realistic experience during the testing phase of the prototype. Without the movement context, the prototype would be a conventional match three game without any relation to the core topic of this work. The movement context allows users to test the VR experience - in relation to the original subject - and give feedback. This feedback is valuable to further improve the prototype and identify possible problems or challenges related to the movement. With the tags introduced in the waypoint system, certain actions can be triggered depending on the position of the cart. The prototype will include two different levels: manual movement context and automatic movement context.

As already described for the first prototype there are two levels. In the first level the players get a hint before each turn which allows them to move a column - depending on the direction - to the left or right. This allows the players to achieve matches that would otherwise not be possible. The players have 5 seconds, after which the function is deactivated and reactivated in the next turn. In principle, this mechanism can be used to trigger any kind of action on the board, although the UI elements that are displayed to

the players can lead to a visual overload. Therefore, it is only possible to move a column in first level. In each left or right turn, 7 additional UI elements (buttons) are activated that can be selected. Each button is assigned to a column and pressing it causes the column to be moved either to the left or to the right. The additional UI elements and the mini-map are shown in figure 4.12.

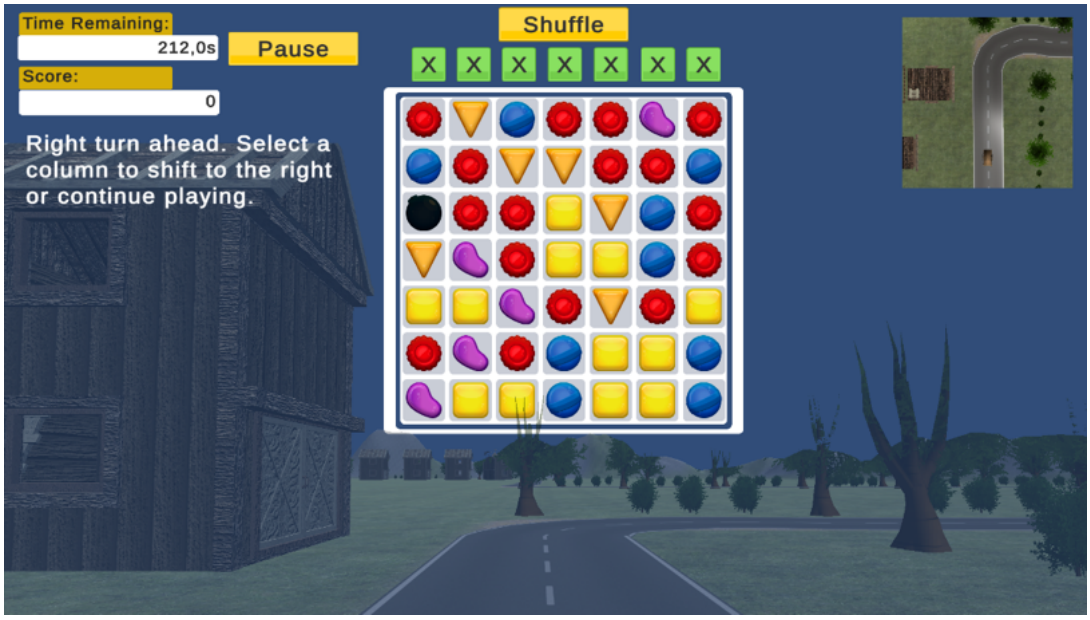

Figure 5.12: The first level features the incorporation of a mini-map and a manual movement context.

In the second level, the movement context is automatically simulated. No additional UI elements are displayed on the screen. The players are informed before each turn that the board will rotate. To ensure that the two levels are distinct, a different transformation of the board has been implemented. The columns are not moved, instead the whole board is rotated either 90 or -90 degrees around the centre point (Gem at position 3,3). This should help to make the game more entertaining and to give the game a certain random character.

CHAPTER 6

Results

6.1 Test Comparison

Each test (T1, T2, T3) could be rated on a scale of 1 to 5, with 1 being the worst and 5 being the best. These rating-based statements contribute to a deeper insight into the perception and experience of the game and the vehicle environment. The ratings obtained were then subjected to statistical analysis. This analysis aimed to provide a quantitative overview of the participants' perceptions of the tests and the game. The statistical evaluation made it possible to generate an objective summary of the ratings based on numerical data.

The visualised results in the boxplot clearly indicate that the third test, which included the multiplayer mode with the projected movement context, received the highest ratings. The evaluation shows that the participants perceived this scenario as particularly positive. The dispersion of the ratings is comparatively low, indicating uniform agreement among the participants. The results of the boxplot thus reflect the qualitative feedback and give it a quantitative dimension. The tendency of the highest rating for the multiplayer test with all features and the lowest rating for the first test gives a clear indication of the participants' preferences and confirms the importance of novelty and innovative game experiences.

	Test 1	Test 2	Test 3
Mean	2,36	3,21	4,36
SD	0,84	0,80	0,74

Table 6.1: Descriptive statistics of the three different test setups.

The ANOVA conducted showed that the null hypothesis can be rejected as the P-value is less than the set significance level of 0.001. This indicates that there is a significant

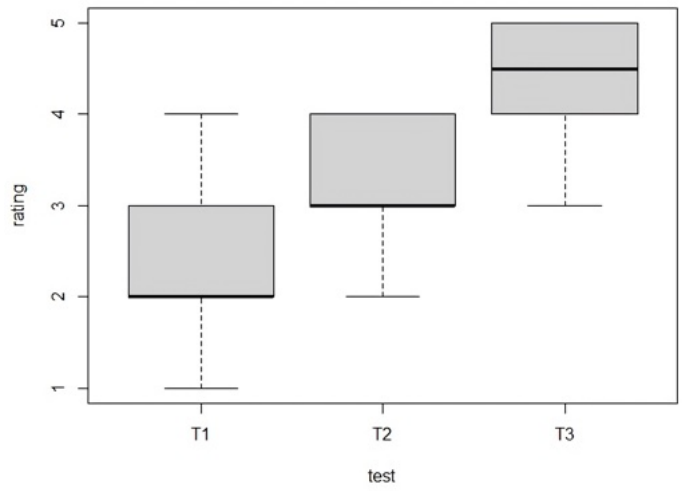

Figure 6.1: Boxplot of the ratings for the three different tests.

difference in the ratings between the game without any features and the game with all features. The low P-value indicates that the probability of the observed difference occurring purely by chance is extremely low. This strengthens the evidence for the alternative hypothesis that the game without features is rated more negatively than the game with all features. These results suggest that the implementation of movement context and multiplayer features has a positive effect on the perception and evaluation of the game. The statistical significance of the difference underpins the importance of these features to the game experience and supports the further development.

	Df	Sum Sq	Mean Sq	F-Value	P-Value
Test	2	28,18	14,095	22,18	0.000000369
Residuals	39	24,79	0,636		

Table 6.2: ANOVA performed on the collected data for the three different tests.

The post-hoc tests - corrected with the Bonferroni method - conducted additionally revealed that the third tests were preferred by the participants. These results deepen the findings from the ANOVA analysis, which already indicated a significant difference in the ratings between the T1 and T2/T3. The preference for the second and third tests, where features such as the implemented movement context and multiplayer features were present, suggests that these elements had a positive impact on perception and enjoyment of the game. The higher scores for these tests indicate that these features enriched the game experience and increased the game's appeal.

These post-hoc results provide a detailed perspective on which specific tests were most popular. This can provide valuable information for future development and optimisation

of the game. The combination of the ANOVA results and the post-hoc tests thus gives a comprehensive view of the participants' preferences and makes it possible to plan targeted steps to improve and further develop the game.

	T1	T2
T2	0,0211	-
T3	0.0000002	0,0015

Table 6.3: Pairwise comparisons using t tests with pooled SD.

6.2 Quantitative Analysis

The evaluation of the questionnaire is a crucial step in the research and forms the basis for further developments and discussions in the project. The data collected from the questionnaire offers valuable insights into the opinions, experiences and attitudes of the participants, which require sound analysis and interpretation.

The process of evaluation begins with data collection and organisation. The collected responses are summarised in a structured form and visualised using appropriate software. In doing so, it is important to ensure that the data is correctly recorded and categorised to guarantee an error-free analysis. MS Forms was used for creating the questionnaire and MS Power BI for visualizing the collected data. Interpreting the results is an important step in understanding the meaning of the patterns and trends found. Here it is crucial to consider the results in the context of the research question. Interpretation can also mean explaining unexpected results or identifying possible reasons for certain patterns.

The results of the questionnaire are not only used to answer the research questions, but also form the basis for further developments and discussions in the project. They can serve as a decision-making aid for the further developments. For example, if the feedback from the participants points out certain weak points, these can be improved in a targeted way to optimise the user experience.

6.2.1 Demographic Information

A significant feature of the participant composition is the age structure. The data analysis illustrates that the 25-34 age group makes up the dominant proportion of participants, 57%. This result indicates a pronounced presence of young adults in the sample, thus revealing a clear pattern of age preference among participants. The demographic analysis contributes significantly to the classification of the data collected. The gender distribution and age structure could potentially have had an impact on the participants' perceptions, preferences and responses in relation to the research topic.

Nearly half of the participants, precisely six individuals, reported that they do not engage in gaming on their smartphones or computers. This group, which has no contact with digital games, represents an interesting contrast to the rest of the participant base. The

remaining participants, consisting of 8 people, indicated that they play digital games at least monthly. This group of participants shows regular interaction with digital games and thus illustrates the existence of an active gaming community among the participants. The disclosure of these gaming habits thus creates further contextualisation of the data collected. The demographic analysis proves to be a valuable tool that not only sheds light on the quantitative aspects of the participant group, but also provides qualitative insights into their digital activities. This deeper understanding forms an essential basis for the targeted interpretation and application of the study results in future developments and discussions of the project.

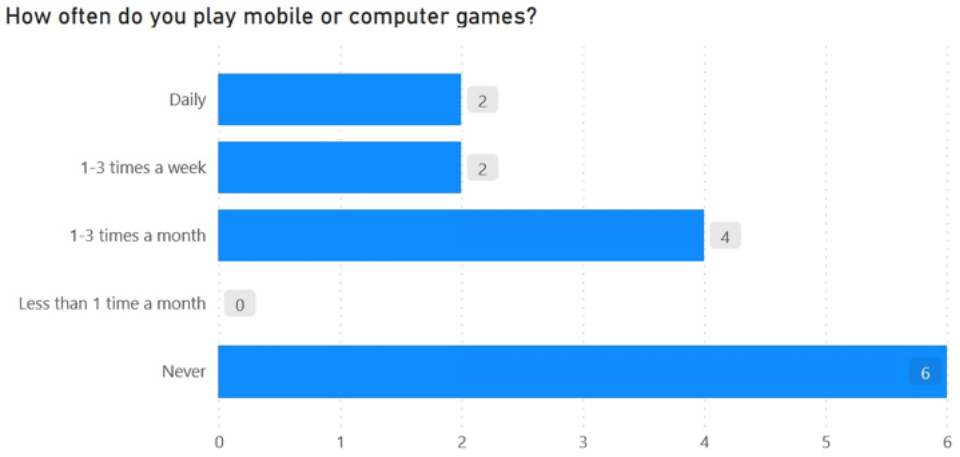

Figure 6.2: Participants' proficiency in mobile and computer gaming.

6.2.2 Game Experience

The analysis of the game experience provides valuable insights into how the participants perceived the game. The results of the questionnaire paint a differentiated picture regarding the comprehensibility of the game principle as well as the game rules. The data make it clear that the majority of the participants understood the game principle well. All but one participant understood the basic game concept. The one person who had difficulty understanding the game principle expressed in the additional comments that they were generally less familiar with digital games. Of particular interest is the fact that this person is in the age group of "55 or older". This observation suggests that age may play a possible role in familiarity with digital games and technology.

The analysis of the results also shows that the majority of the participants, 12 out of 14 to be precise, understood the rules of the game. This indicates that overall the rules of the game were clearly communicated and understood by most participants. Nevertheless, 2 people stated that they found the rules of the game somewhat confusing. These results raise interesting questions and open up potential for deeper analysis. The fact that the person who had difficulty understanding the game principle is older could indicate a possible barrier for older participants in general when interacting with technological

applications or specifically technological applications in vehicles. This could mean that special consideration should be given to the age group when designing and communicating game principles and rules for in-vehicle gaming experiences.

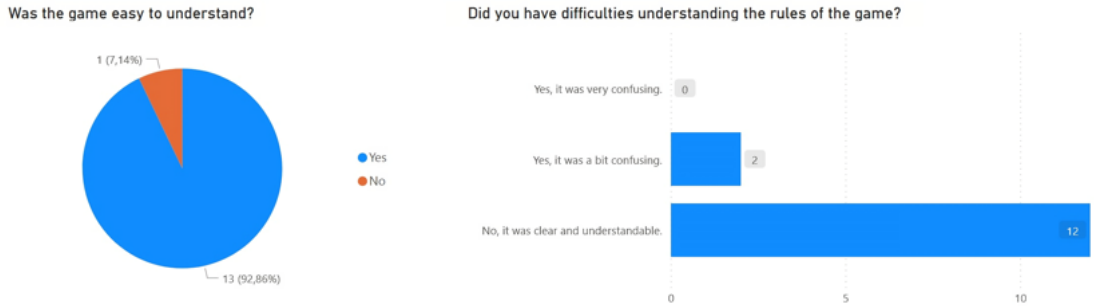

Figure 6.3: Results of the comprehensibility of the game principle and the rules of the game.

The results of the questionnaire indicate that the game mechanics, including swiping and matching, worked effectively in the prototype. The majority of participants had a positive experience with the game mechanics. In particular, swiping and matching - key

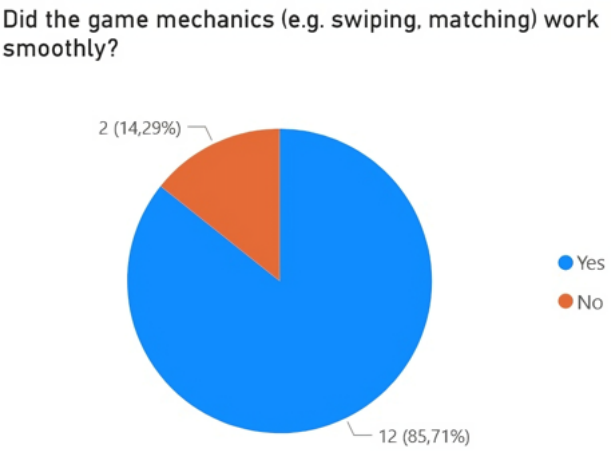

Figure 6.4: The core mechanics worked for the majority of participants. there were two exceptions for testers who played on the tablet.

elements of the game - worked smoothly for most participants. This smooth interaction suggests that the core mechanics have been successfully integrated into the prototypes and have achieved a high level of functionality. This offers potential for future use of these mechanics in further developments or iterations of the game. However, there were also exceptions, as 2 out of 14 people experienced difficulties when swiping or matching. However, these inconveniences were attributed to bugs in the prototype that resulted in degraded performance on the tablet. It is interesting to note that the application

performed better on newer smartphones. This aspect highlights the need for a stable and consistent technical implementation to ensure a consistent gaming experience across different devices.

An overwhelming number of participants received the game as engaging. This consensus underlines the attractiveness and accessibility of match-three games as an entry point into the gaming world. Match-three games thus seem to be a straightforward, yet entertaining way of playing that appeals to a broad target group. This suggests that such games have a low barrier to entry and are also attractive to people who are less familiar with video games. This aspect can be significant when developing games to reach a broad user base, including those who have had little or no previous experience with video games.

The majority of participants felt no frustration during their gameplay. This result illustrates an overall enjoyable gaming experience and indicates the smooth functioning of the core mechanics. However, four people reported feeling frustration at some moments during the game. This frustration was attributed to the some bugs of the core mechanics, which were related to the degraded performance on the tablet. Another notable finding is the positive perception of playing the match-three game in the car. Participants expressed that the game mechanics and gameplay were excellent for in-vehicle entertainment. This finding speaks to the potential of match-three games as an entertaining activity while driving. It was also revealed that most of the participants had a very positive perception of the simulated movement context implemented with the help of the accelerometer. The ability to trigger certain actions by tilting the device in curves was found to be highly amusing by the participants. This underlines the effectiveness of this implementation to create a dynamic and interactive gaming experience. Nonetheless, the motion sickness that occurred during the test drives posed a significant challenge.

Of the 14 test subjects, a total of 6 reported suffering from motion sickness during the ride. This finding highlights the difficulty of developing games for vehicles that are in motion. This problem could be exacerbated in the future, especially if games are integrated with VR devices, as VR is even more prone to motion sickness due to its immersive nature. Recognising this aspect is essential for future developments. It is imperative to consider the safety of users during vehicle use to ensure a pleasant gaming experience that is not harmful to health. The positive reactions to the simulated motion context underline the potentials, but also the need for a sensitive approach to the integration of motion into games for vehicle environments.

The movement of the vehicle did not negatively affect the performance and gaming experience during gameplay. This assessment indicates that the technical implementation of the game was able to maintain a solid performance despite the movement of the vehicle. This reinforces the suitability of the game for use in vehicle environments without negatively impacting the gameplay experience. The participants' opinion also reflects that the movement of the vehicle was not only perceived as unproblematic, but also did not diminish the gaming experience.

Another notable point is the participants' uniform preference for the multiplayer mode

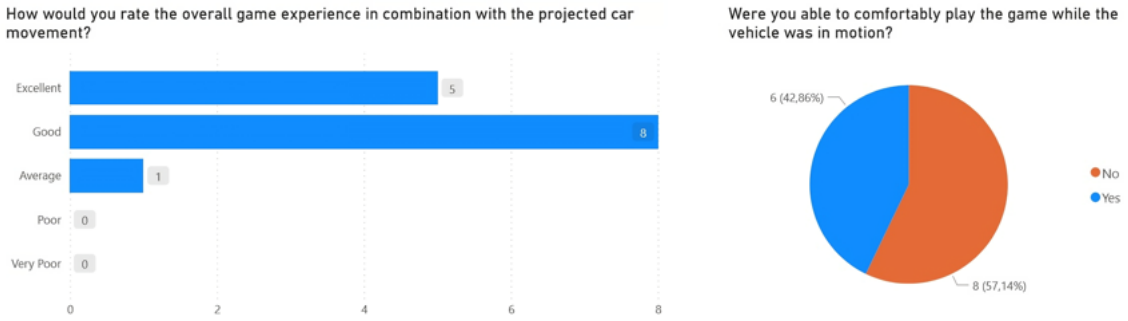

Figure 6.5: The simulated movement context was a successful factor of the positive feedback of the testing sessions. Nevertheless, many users reported motion sickness while playing the game in the car.

(Test 3), which they found most enjoyable. This result emphasises the research question and highlights the social nature of multiplayer games. The fact that the multiplayer mode was found to be most enjoyable by the participants highlights the potential of multiplayer games to promote social interactions during car journeys, which in turn can lead to more passengers in the car.

6.2.3 Visuals and Audio

The analysis yielded positive feedback regarding various design and creative aspects of the game. The graphics, the art style, the animations, the background music and the sound effects were perceived as positive by the participants. All these elements contributed to the atmosphere of the game and supported the overall experience of the participants. The fact that the visual as well as the auditory components were positively evaluated by the participants emphasises the influence of the game and sound design on the emotions and the fun of the players.

6.2.4 Safety and Comfort

Participants indicated that they felt safe while playing in the vehicle. The fact that the participants were wearing seat belts and that the speed limits were strictly adhered to during the test might have increased the feeling of safety. In self-driving vehicles that strictly adhere to the traffic rules, the use of such entertainment mediums would be quite conceivable. The uniform feeling of participants that in-vehicle gaming was perceived as safe emphasises the importance of a prudent and responsible approach when integrating entertainment elements into vehicle environments. Consideration of safety issues and adherence to appropriate measures are essential to ensure the safety and well-being of passengers.

Four participants stated that they had experienced discomfort during the vehicle movements. This uncomfortable sensation can be attributed to the phenomenon of motion

sickness, which was already addressed earlier in the evaluation. The fact that some participants experienced discomfort during vehicle movements again highlights the challenge that motion sickness poses risks for future developments of entertainment options in vehicle environments.

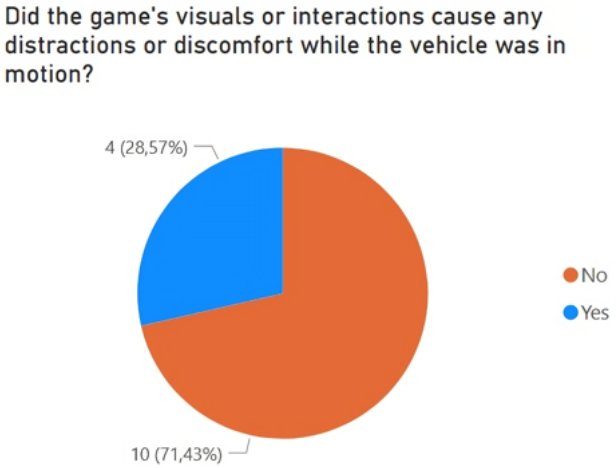

Figure 6.6: Prevalence of distractions, discomfort, and motion sickness among the participants during vehicle motion.

6.2.5 Economical and Social Factors

The majority of the participants showed a positive reaction to the social aspect of the multiplayer mode. This shows that the possibility to interact with other passengers in the car and to play together is perceived as motivating. The link between multiplayer aspects and the motivation to ride in the car with as many passengers as possible emphasises the social component of games in car environments. These findings support the original assumption that multiplayer elements in vehicle games can help to promote social interaction among passengers and thus enhance the shared experience while driving.

About half of the participants (43%) expressed the view that they would use offers such as carpooling or ride-sharing to play games with other people. This finding illustrates the potentials that can arise from integrating games in shared vehicles. Particularly noteworthy is the differentiated opinion of one person who stated that they would not make use of such services because of multiplayer games. This attitude was attributed to the older age of the person, who is in the age group "55 or older". This result sheds light on possible generational differences in the perception of games and the willingness to use carpooling or ride-sharing services.

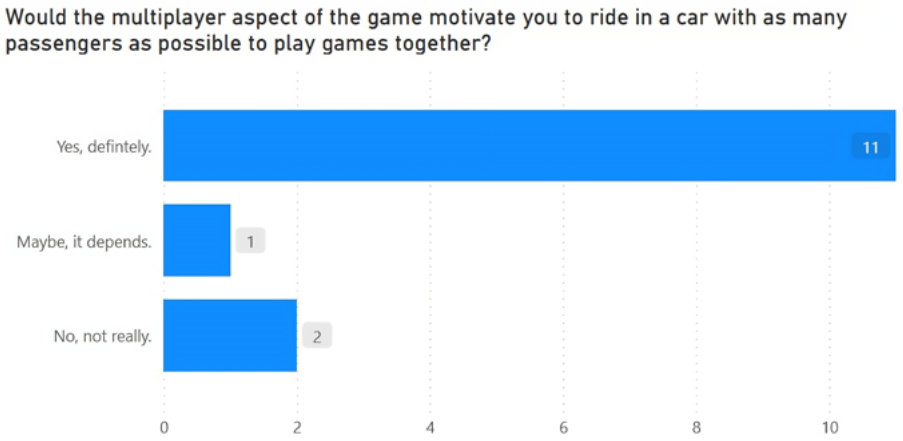

Figure 6.7: Multiplayer game dynamics have the potential to serve as a motivating factor for passengers, encouraging engagement with a greater number of co-passengers during the gaming experience.

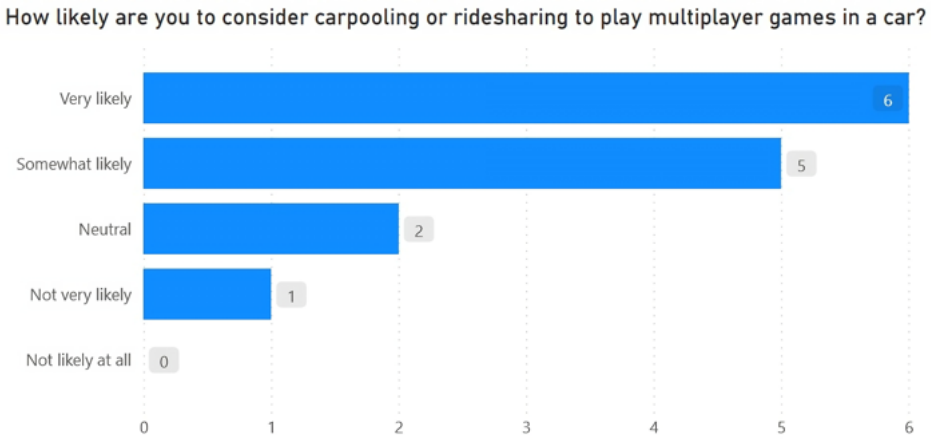

Figure 6.8: Multiplayer gaming has the potential to incentivize and facilitate increased adoption of carpooling and ride-sharing practices

These results show that the social aspect is central to the design of games for vehicle environments. The ability to interact with other passengers in the vehicle or even with other vehicles in the environment can enrich the gaming experience and help promote social interactions while driving.

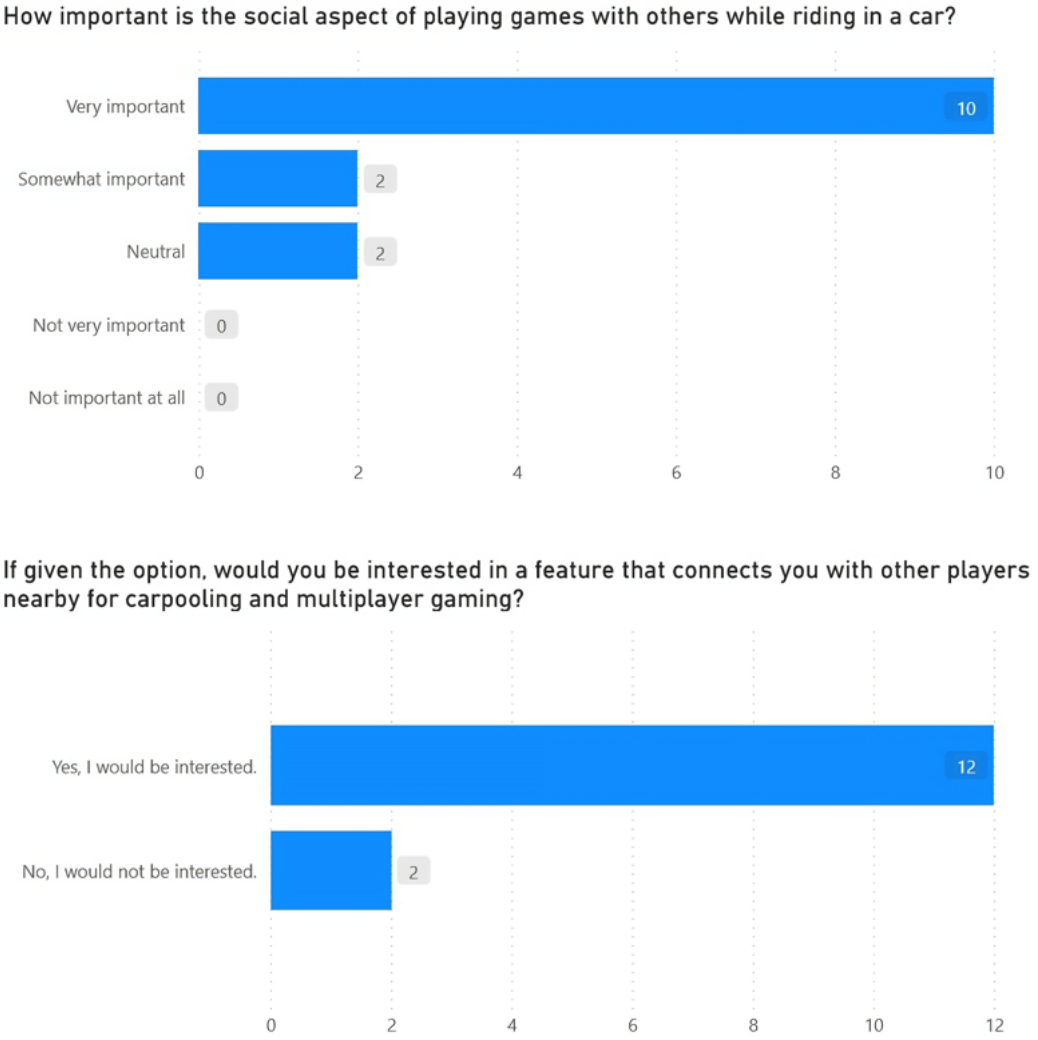

Figure 6.9: The incorporation of a feature that establishes connections between players and individuals in their immediate proximity has the potential to enhance motivation and augment the overall enjoyment derived from the gaming experience.

The high level of agreement on the preference for playing together highlights the opportunity to create gaming experiences that can strengthen not only the game itself, but also interpersonal relationships and social interaction while driving. This again emphasises the potentials of combining games and vehicle environments to create positive and enriching driving moments.

Opinions regarding the influence of multiplayer games on sustainable transport options were split among the participants. While 9 people believed that multiplayer games are helpful and can contribute to promoting more sustainable transport options, 5 people believed that the influence of multiplayer games on sustainable transport options would be

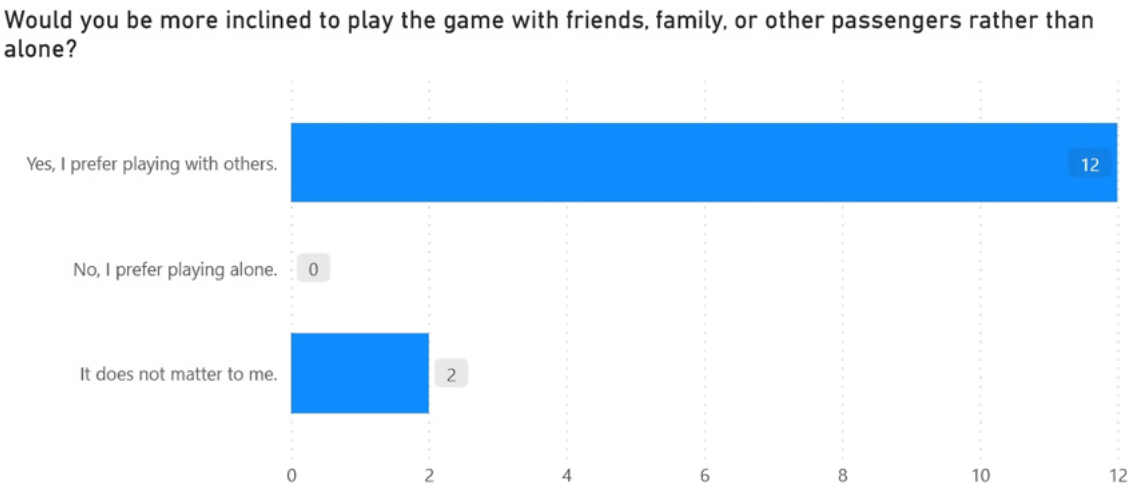

Figure 6.10: Analysis of gameplay preferences among participants reveals a predominant inclination toward multiplayer experiences over singleplayer haming.

rather minimal. This split opinion reflects the complexity when it comes to assessing the impact of games on behaviour change related to transport habits. Those who believe that multiplayer games can help promote more sustainable transport options might assume that playing games together could increase interest in shared trips such as carpooling or ride-sharing. This could be supported by the social aspect of in-vehicle gaming and the ability to share the gaming experience with others. The people who assumed a lower impact of multiplayer games on sustainable transport options might consider that other factors have a greater influence on transport choices and that games alone cannot significantly influence these decisions.

The questions on the perception of the potential environmental benefits of carpooling or ride-sharing revealed a dominant opinion among the participants. The majority of respondents expressed that they would participate in such offers because of their intention to protect the environment. This indicates an increased environmental awareness and that the environmental benefits of shared transport options are an important incentive for participation. Interestingly, 4 participants expressed the opinion that the overall concept of carpooling or ride-sharing would not make a difference to them. This could indicate that these participants value other factors than the potential environmental benefits when deciding on transport options. The participants' strong endorsement of environmental protection as an incentive to participate in shared transport options is a positive signal. This shows that awareness of environmental aspects plays a relevant role in the decision on the choice of transport mode. This in turn could point to the potential of using games in vehicles to raise awareness of environmental issues and emphasise the positive impact of more sustainable transport options.

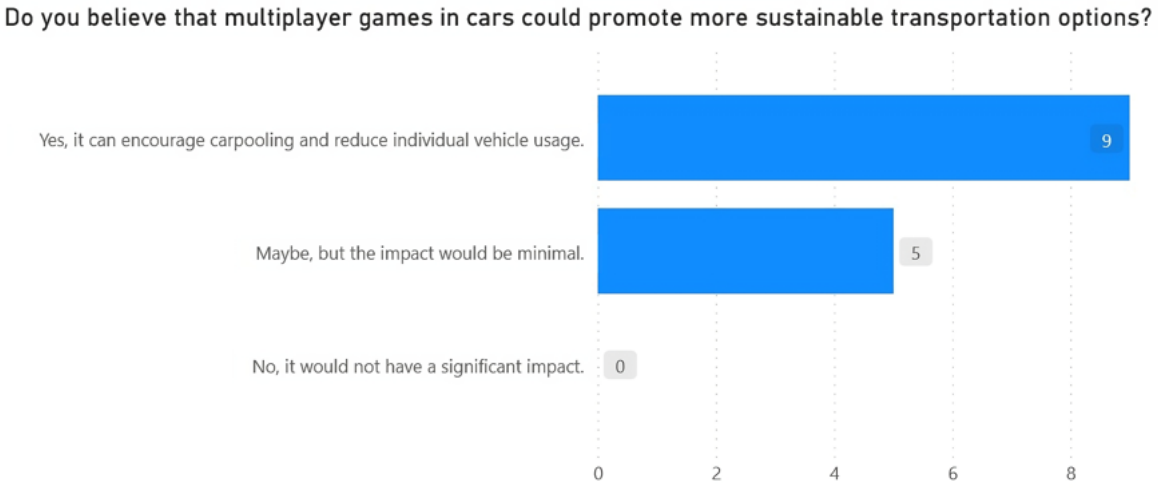

Figure 6.11: Multiplayer games, if well implemented and embedded in the vehicle context, could provide more sustainable transport opportunities in the future.

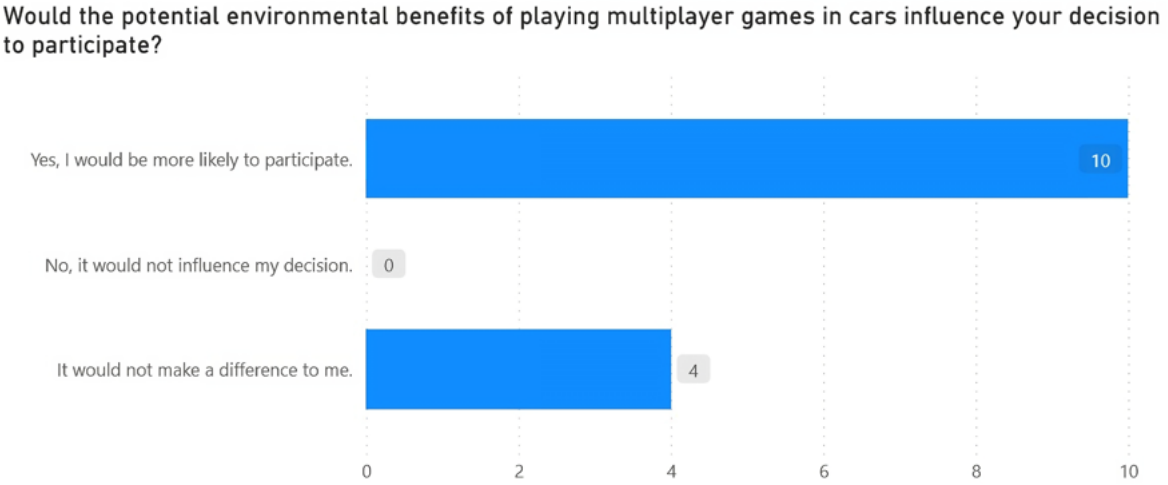

Figure 6.12: The majority of participants would take part in services such as carpooling or ride-sharing as this would help to protect the environment.

6.2.6 Suggestions and Feedback

In the final section of the questionnaire, participants provided valuable additional feedback on the game. Some participants expressed the wish that it should be more clearly highlighted in multiplayer mode which player they are. This point shows that game explanation and visual differentiation of players in multiplayer mode play an important role in avoiding confusion and improving the game experience.

Furthermore, it was reported that some bugs occurred in the game and that the per-

formance was worse on the tablet. This feedback is significant as it points to potential technical improvements and shows that participants were paying attention to the technical aspects of the game. This supports the intended development cycle, which includes continuous iterations and improvements to optimise technical stability and the game experience.

The idea of implementing the game on the VR platform was also highlighted. This shows the potential for enhanced gaming experiences on innovative platforms. The comment that games on smartphones and tablets are no longer novel emphasises the relevance of innovation and differentiation to engage players. The consideration of realising the game on the VR platform underlines the need to pay attention to trends and emerging technologies in order to maintain the game's appeal in the long term.

Overall, the feedback from participants highlights the importance of an agile development approach based on continuous feedback. Identifying bugs, performance issues and requests from participants allows for targeted optimisation of the game and maximisation of gameplay enjoyment. These insights are invaluable for the future development of the game and emphasise the need to focus on technical improvements, player experience and innovation.

CHAPTER 7

Discussion

This research aimed to develop an understanding of how multiplayer games can be designed specifically for in-vehicle entertainment. Various aspects were considered, including technical implementation, user experience, integration of motion contexts and network functionalities. The results of this study offer valuable insights into the challenges and potentials of this emerging area of in-vehicle entertainment.

RQ: What features and elements should be incorporated into an in-vehicle multiplayer game to encourage carpooling with shared roles among players?

The results of the study indicate that implementing multiplayer features and interactive movement contexts in a game is able to enrich the gaming experience during the journey and has the potential to engage more passengers in a shared gaming experience. This is supported by the positive ratings of the third test, which included the multiplayer mode with all features. A crucial point that became clear during the research is the importance of an accurate and realistic movement context. This movement context reflects the driving situation and conditions and is crucial for the game experience. It is important to note that the movement context needs to be carefully modelled to reflect the actual driving experience as accurately as possible. This includes accounting for acceleration, cornering, speed changes and other vehicle movements.

Participants' preference for the third test, which included the full-featured multiplayer mode and a simulated movement context, indicates that the mapping of driving conditions has a significant impact on the game experience. This highlights the need to implement the movement context realistically using the OBD to create an authentic gaming experience [10]. The use of motion-controlled features has also yielded promising results. Although this approach is not as realistic as movement context via OBD, it has shown the ability to keep passengers entertained and engaged in the game experience while driving [9].

The experiment conducted has provided significant new insights into the close link between game enjoyment and social interaction in multiplayer games. These findings deepen the

understanding of how social interaction positively influences the game experience and increases game enjoyment. It has been suggested in the past that the ability to interact socially in multiplayer games increases game enjoyment [16]. However, this experiment has concretely shown that this assumption is by no means unfounded, but is based on actual findings. Social interaction allows players to play not only against but also with each other. It promotes cooperation and competition in equal measure and creates a sense of community and cohesion.

The lower scores for the first test, which involved playing on a smartphone with no additional features, underline the importance of innovation in the design of games for vehicle environments. Participants found this scenario less engaging as it did not offer any new or unique elements. This underlines the need to design games for in-vehicle environments in a way that differentiates them from traditional game offerings and adds value. Implementing the game on the XR or VR platform would definitely be an innovation in this area [18].

Unity supports the integration of network functions and offers developers the possibility to create cross-platform multiplayer games that work on different devices and operating systems. A clean network architecture is crucial to ensure scalability and maintainability of the game. Netcode for Gameobjects in conjunction with Unity Relay provides a smooth, low-latency gaming experience. Khan et al. [12] have already shown in their work how crucial the network functionalities are for the user experience and the interactive gaming experience. These findings confirm the results of the present study and underline the importance of carefully designing network features in multiplayer games, especially in the unique environment of vehicles.

7.1 Limitations

The methodological choices made in conducting this study were crucial to achieving the research objectives within the given framework. However, the limitations in terms of available equipment also played a significant role. It is important to note that the use of additional hardware, such as microcontrollers or special interfaces for data collection, is beyond the scope of this work and therefore could not be implemented. This had some implications for the experimental setup and data collection. The lack of access to special hardware components particularly affected the collection of movement data in the vehicle. Despite these limitations, the study offers valuable insights into the integration of in-vehicle entertainment options. Another methodological decision was related to the selection of test participants and the execution of the experiments. As the study took place in a real vehicle environment, safety aspects and compliance with traffic rules had to be given top priority. Therefore, the number of test subjects was limited to ensure that the experiments could be conducted safely. this also explains why the test subjects were recruited from an already known social network. The experiment could be conducted with more participants given a suitable legal framework.

CHAPTER 8

Conclusion

The analysis of the results from the prototype study provides important insights into the participants' perceptions and preferences in relation to games in vehicle environments. The results highlight the multiple aspects that need to be considered when designing entertainment options for occupants in vehicles. The conclusions suggest various trends and potentials that may be relevant for future developments of games and entertainment services in vehicles. The acceptance of multiplayer games and the strong desire for social interaction while driving are prominent findings. The fact that multiplayer mode was identified as the most popular mode and the desire to play games with fellow passengers is high emphasises the role of games as a critical element for social interaction and shared activities during the ride. This demonstrates the potential for entertainment to enrich the driving experience and promote the positive aspects of carpooling.

The inclusion of environmental considerations in transport choices is also significant. The high approval of shared transport options due to environmental protection shows that games in vehicles can not only be used for entertainment, but also as a tool to promote more environmentally conscious behaviour. This can contribute to creating awareness for sustainable transport options and thus have a positive impact on mobility.

The findings on technical improvements and wishes of the participants, such as highlighting the player status in multiplayer mode and implementation on VR platforms, illustrate the importance of an agile development process based on continuous feedback. These findings form a valuable basis for the further development of the game and emphasise the relevance of user orientation and technical quality.

Overall, the results of the prototype study provide a clear path for the design of a multiplayer game with shared roles in vehicle environments. The findings emphasise the social aspect, the integration of environmental aspects, technical optimisation and the exploration of innovative technologies such as VR. The combination of these factors could help create a gaming experience that is not only entertaining, but also enriches

the driving experience, promotes social interactions and encourages people to be more environmentally conscious.

8.1 Future Work

The present study on the evaluation of games in vehicle environments has provided valuable insights into the preferences and perceptions of the participants. The positive response towards the prototype underlines the potential of games as entertainment options while driving. However, this study is only the first step in a broader research addressing the design and implementation of entertainment options in future mobility concepts.

The success of this prototype study confirms the relevance of games in vehicle environments and shows that there are multiple opportunities for improvement and expansion. Based on the insights gained, targeted adjustments and further developments can be made to optimise the gaming experience. In particular, technical stability and improvements for the multiplayer mode are essential aspects that should be considered in future development iterations.

A particularly promising approach for the future would be to implement the game on VR platforms. This project would have the potential to establish a completely novel form of entertainment in vehicles. Virtual reality could take the gaming experience to a new level and create an immersive entertainment experience that both engages passengers and enables a new dimension of interaction while driving. Researching and implementing games on VR platforms in vehicles requires a holistic view of technological, ergonomic and social aspects. The design of such an experience would not only include the development of game mechanics and visual elements, but also the integration of VR technologies into the vehicle environment and the consideration of aspects such as motion sickness and safety.

Overall, this study marks the beginning of an exciting journey that will continue to explore and develop the potential of games in vehicles. The goal of creating a novel form of in-vehicle entertainment and interaction remains a key concern going forward. The insights gained from this prototype study provide a solid foundation on which future developments can build to design an innovative and enriching driving experience.

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Bibliography

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APPENDIX A

Questionnaire

Question	Answers
1. Age	* Under 18 * 18-24 * 25-34 * 35-44 * 45-54 * 55 and older
2. Gender	* Woman * Man * Non-binary * Prefer not to say
3.How often do you play video games?	* Daily * 1-3 times a week * 1-3 times a month * Less than 1 time a month * Never

Table A.1: "Demographic Information" section of the questionnaire.

Question	Answers
4. Was the game easy to understand?	* Yes * No
5. If no, please provide details on what aspects were unclear or challenging.	Free Text
6. Did you have difficulties understanding the rules of the game?	* Yes, it was very confusing. * Yes, it was a bit confusing. * No It was clear and understandable.
7. Did the game mechanics (e.g., swiping, matching) work smoothly?	* Yes * No
8. If no, please explain any issues or difficulties you encountered.	Free Text
9. How engaging did you find the game?	* Very engaging * Somewhat engaging * Neutral * Not very engaging * Not engaging at all
10. Were there moments when you found the game frustrating?	* Yes * No
11. If so, can you describe those moments?	Free Text
12. How would you rate your overall experience playing the match-three game in the car?	* Excellent * Good * Average * Poor * Very poor
13. How would you rate the overall game experience in combibation with the projected car movement?	* Excellent * Good * Average * Poor * Very poor
14. Were you able to comfortably play the game while the vehicle was in motion?	* Yes * No
15. Did the car movement affect your gameplay performance or enjoyment?	* Yes * No
16. If so, can you describe what affected your gameplay?	Free Text
17. Which game mode have you enjoyed most?	* Singleplayer * Multiplayer * Both equally

Table A.2: "Game Experience" section of the questionnaire.

Question	Answers
18. How would you rate the graphics and visual appeal of the game?	* Excellent * Good * Average * Poor * Very poor
19. How would you rate the audio effects and background music?	* Excellent * Good * Average * Poor * Very poor.

Table A.3: "Visuals and Audio" section of the questionnaire.

Question	Answers
20. Did you feel safe and secure while playing the game in the vehicle?	* Yes * No
21. Did the game's visuals or interactions cause any distractions or discomfort while the vehicle was in motion?	* Yes * No
22. Were the game's design and interaction elements appropriately tailored to ensure a safe and enjoyable experience?	* Yes * No

Table A.4: "Safety and Comfort" section of the questionnaire.

Question	Answers
23. Would the multiplayer aspect of the game motivate you to ride in a car with as many passengers as possible to play games together?	* Yes, definitely. * Maybe, it depends. * No, not really.
24. How likely are you to consider carpooling or ridesharing to play multiplayer games in a car?	* Very likely * Somewhat likely * Neutral * Not very likely * Not likely at all
25. If given the option, would you be interested in a feature that connects you with other players nearby for carpooling and multiplayer gaming?	* Yes, I would be interesed. * No, I would not be interested.
26. How important is the social aspect of playing games with others while riding in a car?	* Very important * Somewhat important * Neutral * Not very important * Not important at all
27. Would you be more inclined to play the game with friends, family, or other passengers rather than alone?	* Yes, I prefer playing with others. * No, I prefer playing alone. * It does not matter to me.
28. Do you believe that multiplayer games in cars could promote more sustainable transportation options?	* Yes, it can encourage carpooling and reduce individual car usage. * Maybe, but the impact would be minimal. * No, it would not have a significant impact
29. Would the potential environmental benefits of playing multiplayer games in cars influence your decision to participate?	* Yes, I would be more likely to participate. * No, it would not influence my decision. * It would not make a difference to me.

Table A.5: "Economical and Social Factors" section of the questionnaire.

Question	Answers
30. What improvements or additional features would you like to see in the game?	Free Text
31. Any other comments, suggestions or feedback you would like to share?	Free Text
32. Any other thoughts, suggestions or comments regarding the economical factors or multiplayer aspect of the game?	Free Text

Table A.6: "Suggestions and Feedback" section of the questionnaire.