Fitness and Exercising in Virtual Reality

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MASTER THESIS

Fitness and Exercising in Virtual Reality

An Interaction Design Master Thesis

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Abstract

Virtual Reality technology has advanced forward in a world where physical fitness is not always a natural part of everyday life. But must one thing be traded for the other? VR lets users immerse themselves in an entirely virtual world where interaction is possible through physically moving around in the real world. So, is it possible to combine VR with exercising? That is what this master thesis aims to discover, attempting to fuse the two together with gamification.

A Virtual Reality application was built, relying on user input as it was developed. Several types of exercises were implemented, and everything was joined together by a gamified system of gaining points and trophies. 21 people participated in formal testing.

The app received overall positive feedback, but still lacked in variety and execution. Interacting in a 3D user interface was not as intuitive as expected, and the participants did not always feel that their goals in the exercises were clear enough. The participants nevertheless felt immersed in their experience and voiced the general opinion that they saw potential in the app.

For the future, it seems that an app like this is viable, but needs much more time to be developed and tested.

Keywords: Virtual Reality, Fitness, Gamification, Interaction, Immersion

Sammanfattning

Virtual reality-teknologi går framåt i en värld där fysisk hälsa inte alltid är en naturlig del av vardagen. Men måste en sak bytas ut mot den andra? VR låter användare helt uppslukas av en virtuell värld, där interaktion sker genom fysiska rörelser i den riktiga världen. Så är det möjligt att kombinera VR med träning? Det är vad detta examensarbete undersöker i ett försök att slå samman VR och träning med hjälp av spelifiering.

En Virtual reality-app byggdes med hjälp av kontinuerlig återkoppling från användare. Flera typer av träningsövningar implementerades och appen knöts samman med hjälp ett spelifierat system med poäng och trofféer. Sedan genomfördes en formell användarstudie med 21 deltagare.

Appen fick överlag positiv återkoppling, men saknade fortfarande variation i sitt innehåll. Interaktion i ett 3D-användargränssnitt var inte s intuitivt som hade förväntats, och testdeltagarna kände inte alltid att deras målsättning under övningarna var tydlig nog. Men testdeltagarna kände ändå inlevelse i sin erfarenhet och den generella åsikten var att appen hade potential.

Inför framtiden så verkar appen lovande, men behöver mycket mer tid att utvecklas och testas.

Nyckelord: Virtuell verklighet, häsla, spelifiering, interaktion, inlevelse

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Lastly, I extend a thank you to the entire Department of Design Sciences at Lund University for their several years worth of interesting courses and projects that have lead me here to this thesis as the culmination of my studies.

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Chapter 1
Introduction

We are bound at work to our office chairs, and at home to the TV sofa and the computer room chair. When we should spend hours walking and running and moving about each day, instead we sit. There are studies showing an increase in mean body mass and a decrease in aerobic capacity in young males [1]. Paired with the prevalence of fast food, sugar and unhealthy products, the recipe for a fitness disaster is clear. So what can we do in this day and age to get healthier? Shall we just abandon all our modern habits and discard the newly developed technology that confine us indoors? Or should we embrace it to find a new solution?

Exercising is a vital component to health and fitness. But it can be difficult to muster the willpower to complete the required amount of exercising that is required. Meanwhile, the video game industry has spent years perfecting the art of creating addictive games that make use of the primal drives and functions of the human brain. Perhaps it is possible to combine the two? In order to bring gaming and fitness together, a powerful interface and interaction system is required, something that only recent technology has given us. Virtual reality (VR) fits this bill perfectly. VR lets the user immerse themselves completely in a virtual world, all while they interact by pointing, walking, and moving about in the real world instead of just sitting. With VR technology only reaching this level of quality in recent years, there is still huge room for discovery and experimentation.

Other attempts to combine VR or similar technology with exercising already exist though. Pokémon Go is a famous one, where users walk around outdoors to reach different geographical spots [2]. For pure VR exercising, games like BOXVR [3] and Hot Squat [4] exist, letting users engage in physical activities that translate into the games using tracking technology. These games are available for sale on the digital distribution platform Steam. All of these games have been developed these past few years, so the area is still a new frontier, and the technology to support it has just started to get mature. Aaron Stanton of the Virtual Reality Institute of Health and Exercise also states that VR is "the most effective piece of exercise equipment he's ever purchased". He says that according to his findings, exercising in VR is both effective and the exercisers don't notice the pain of exerting themselves to the same degree [5]. Finally, there are even applications that combine VR with real exercising equipment. Black Box VR features a real gym built around a VR app with not only bodyweight training, but also resistance training with weights [6]. The Black Box gyms are not widespread though and you can't bring them with you home. And then there is CycleVR, a project where a lone biker traveled across the United Kingdom, and he did it on a stationary bike through VR and Google Street View [7]. The possibilities are many, and more and more projects are starting to emerge.

This shows that there is both interest and a great potential in this type of work.

1.1 Purpose and Goal

The purpose of this thesis is to build a VR application where a user can conduct physical exercises. The application will then be evaluated and conclusions will be drawn on the viability of combining VR, physical exercising, and gamification.

A few concrete goals have been chosen:

- Develop a virtual reality application which a user can successfully conduct physical exercising using the application and the room-scale VR of the HTC Vive.
- Explore how physical exercising, VR, and gamification work together.
- Identify both interactions and scenarios that work well and ones that don't.
- Attempt to pinpoint contributing factors to these discoveries using scientific theory combined with test data collection and participant background information.
- Use an agile development approach and user-centered design

The VR application developed in this project will be referred to as the *FitnessVR App*.

1.2 Scope and Limitations

Due to shortage of time and resources, the FitnessVR App will be limited to a select few fitness exercises of general character. Specializations, such as specific rehabilitation exercises and similar, will not be implemented. Each exercise will be limited in depth and will be as straight-forward and simple as possible.

The FitnessVR App will also be tailored for only a 15-30 minute experience, which is what the length of the user tests is expected to be. The amount of test sessions per participant will be set to one.

The general nature of the fitness exercises is to appeal to a wider audience. No additional exercising equipment beyond the VR hardware will be used. This is because the the FitnessVR App is envisioned as something that can be used at home by anyone with a VR setup, requiring no specialized exercising equipment or additional monetary costs. This also serves to keep the target audience wider, making it easier to find potential users for the tests and putting less restrictions on end product. Requiring a VR setup is already restricting as it is.

Chapter 2

Theoretical and Technical Background

In this section all the underlying theory used for the development, user tests and the data analysis will be discussed.

2.1 Agile software development

To develop the VR application, an agile software development method was chosen. This can be described as a development methodology that prioritizes working software over documentation, and that promotes adapting to change rather than strictly adhering to a pre-prepared plan. According to Martin [8], some of the principles of agile development are:

- Satisfy customer by early and continuous delivery of software
- Be welcoming of changing requirements
- Continuous interaction between developers, customers and stakeholders

Much but not everything of agile software development suits the nature of this thesis, largely due to its exploratory nature and dependence on learning what to do during development. Some aspects of agile software development were omitted due to the work largely being a one-man effort rather than developed by a team.

In agile development, the development should start with an initial exploratory phase where use cases and requirements are identified. Then iterations are planned; the duration of a development iteration is chosen and the specific things to implement are picked [8]. Figure 2.1 is the simplified agile development process used to create the FitnessVR App.

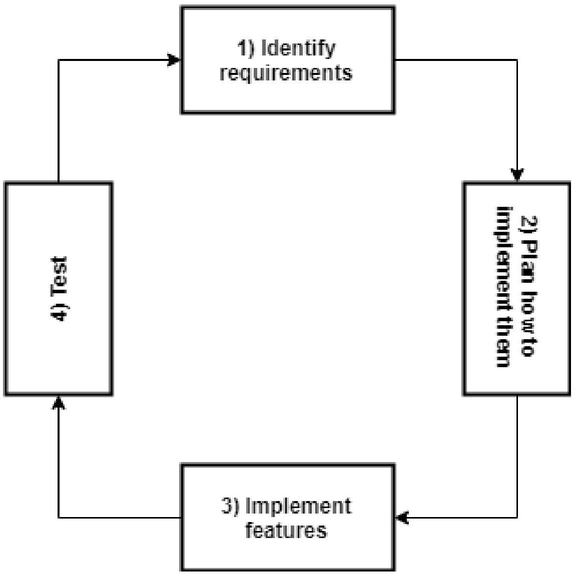

Figure 2.1: Simplified agile development cycle.

2.2 Behavior change

To construct a VR application that somehow is a useful complement to exercising normally, the use of that application for exercising must affect the users behavior and introduce additional motivation. Otherwise the application is of no use for those purposes.

According to Wendel [9], the process of designing behavior change can be divided into the four stages:

- **Understand** the mind and how it behaves
- **Discover** the behaviors you want to change
- **Design** the product around that behavior
- **Refine** the product based on input and analysis

According to this, the process of designing behavior change should not start with building the software. First, one must identify the actions where a behavior change is desired. Then, those actions must be re-imagined. Only then can the software be built and later refined.

Wendel also highlights a number of ways to specifically increase the motivation of the user. A few examples of this are:

- Highlighting a user's existing motivation.
- Give rewards for taking an action, and punishments for not doing it. But punishments should be avoided if possible.
- Translate future benefits of taking an action into something real in the present.

2.3 Virtual Reality

Virtual reality (VR) is a computer-generated environment in which everything the user sees is part of this virtual reality. VR is usually experienced through a VR-capable head-mounted display (HMD). The virtual world can use room-scale, meaning that the user moving around in the real world translates to an equal movement in the virtual world [10].

In a VR environment and with the hardware that comes with the VR setup, exercising can be tracked and data gathered. Exercises can be enhanced or placed in gamified scenarios to help increase the sense of presence, immersion and motivation. Hopefully, the combination of the fields of fitness, VR and gamification can create a framework for physical exercise toward fitness that is fun and easy to use. A system that is capable of analyzing the quality of the physical exercise and giving motivating feedback based on that.

2.3.1 HTC Vive

The HTC Vive is a VR headset. It supports room scale tracking, allowing the VR system to track the user's position in a real room. This capability is essential for a physical exercising VR app, since the user must be able to physically move about and have that movement reflected inside the game world [10]. Below is a list of components needed for the HTC Vive setup:

- **1 head-mounted display (HMD)** - Mounted across the face, it allows the user to see into the VR world through its display. It also enable the user to look around in the VR world.

- **2 hand controllers** - Hand-held controllers with buttons. The user can move them around to also move their hands inside the VR world. Each controller has one Trigger Button, one Teleport Button, and one Grip Button.

- **2 lighthouse beacons** - Devices places in two corners of the play area. They track the position of the HMD and hand controllers. This is called *room-scale tracking*.

- **1 computer** - To use the HTC Vive, a computer is needed. The game runs on the computer. The HMD is connected to the computer via cords.

Furthermore, the HTC Vive provides a horizontal field of view (FOV) of 100 horizontal degrees and 110 vertical degrees. All of the Vive components can be seen in Figure 2.2

Figure 2.2: The HTC Vive, showing the HMD, hand controllers and lighthouse beacons.

2.3.2 Unity

Unity is a cross-platform game engine. It has been chosen to develop the system for a number of reasons:

- It supports the creation of 3D games
- It has a thriving community creating visual and auditory assets that can be used for game development
- It comes with well-working assets for making games that support the HTC Vive and VR development

The author also has prior experience developing VR applications in Unity, making this game engine the most efficient choice for achieving rapid development [11]. Other similar 3D game engines exist, such as Unreal Engine [12].

2.4 Presence and Immersion

According to Bowman et al. [13], presence can be defined as *"the feeling of being there"*. It is one of the key components of this project. Bowman et al. claim that presence makes sense for applications such as gaming, training and simulation, all three of which are essentially intended to be a part of the final product of this thesis. They say one way to increase the sense of presence and to also make the application more intuitive, is to embrace the possibilities of a 3D user interface. A 3D VR world, where the user has one controller in each hand, can be interacted with using some of the natural interaction skills the user has already accumulated in the real world. Therefore, it has been decided that the design of the application will take into account how the user would expect to interact with objects in the real world, and attempt to translate that into the VR world. Feedback from the system should be as immediate and direct as possible [13].

The intent is to build an immersive system. To identify the difference between presence and immersion, we will look at definitions made by Tony [14]. Immersion relates to how well the system can substitute elements of the real world. Immersion is governed by factors such as display screen resolution, haptic feedback (like vibrations) [13], audio feedback, etc. Things such as the visual fidelity of a virtual environment, and haptic and audio feedback from system events will need to be considered.

The main focus of the system created in this thesis should be to create presence through immersion and the gamification of fitness. The goal is for the user to engage in fitness and exercising and become motivated. Immersion will be one aspect to achieving this. Another factor will be how well the exercises are gamified, which includes both the game mechanics of real-time interaction and feedback, and the gathering of data which can be displayed to the player post-exercise.

2.5 Gamification

This section will discuss the concept of gamification, with the intent of clarifying it and defining various related terms. This will help provide a framework for interpreting and quantifying results and conclusions.

According to Deterding et al. [15], gamification is defined as the use of game design elements in non-game contexts. An example of gamification can be the use of points, badges, levels and leaderboards. Deterding et al. also says that *playfulness* is a desirable quality of the user experience. Playfulness is described as "fun" or "pleasurable experience", and can be any action that goes beyond the bare minimum work.

Game should also be distinguished from *play*, which is important in the context of this system. Play is generally more free-form and improvisational. A game is structured by rules and marked by striving toward a specific goal. That is what the FitnessVR App will be trying to emulate, since physical exercises are inherently in need of being structured physical activities repeated accordingly to a framework designed to reach a goal. The goal is to achieve or maintain fitness.

Game elements are the building blocks of the game and can be composed of actions performed by the user or of entirely virtual components. To constrain the definition of the term game element in a meaningful way, the definition from Deterding et al. [15] will be used: a *game element* is an element that is characteristic for a game. Several examples of such elements are discussed in further detail in the sections detailing VR and 3D user interfaces [15]. The term will also be used in the results to identify components of the FitnessVR App.

An important aspect is also that the outcome of the game scenario should be quantifiable. *Proof of progress*, a term described by Donais [16], perfectly captures the essence of one of the design principles to be used for gamifying fitness. Inside the game environment and world, every action will lead to a form of progress. In the real world, this progress comes over time in the form of improved fitness and on the short term it is made evident by fatigue in the user from conducting physical exercises. Inside the virtual world, the system must help the user see this progress. It must be integrated into the game and the virtual environment. The player must have a proof of their progress. Proof beyond what the real world offers, since the whole idea of the project is to use VR to augment what is already possible using no equipment at all. This is intended to evoke a feeling of progress, which is the heart of it, just as a sense of presence is a key component of the system as a whole. So the system implementation will include a means to show the user proof of their progress in the game and of their real-world level of fitness.

Ways to show proof of progress can be through leveling up accordingly to a leveling curve, gaining skill and experience points, obtaining rewards and items, unlocking areas and abilities, and gaining access to new means of interaction [16].

In the game the player must have tasks, doubling as physical exercises, to perform. There must be a goal, preferably something beyond only conducting the exercises just for the sake of it. The intent is that the player will complete the tasks, i.e. the exercises, in pursuit of achieving the goal. The feedback and sense of progress and reward will be stronger than what the real world offers. Existing on a higher level than each individual goal, which can be a game level or a sub-part of a game level, there must also be an overarching progression and proof thereof. This makes each task and each goal achieved part of a bigger whole. This bigger whole is, in the real world, the general fitness of the user, just as each task and level in the games represent exercises and exercise routines.

Lastly, the user should also have a sense of attachment to the outcome of their action [17].

2.5.1 Gamification highlights

Here are a number of key highlights about gamification to remember [15].

- **Game** - A game is structured by rules and marked by striving toward a specific goal.
- **Game element** - The actions and components of a game.
- **Gameful** - Relating to the qualities of playing a game.
- **Gamification** - The use of game elements in non-game contexts.
- **Proof of progress** - Showing the player that they have progressed.

2.6 Fitness and Exercising

There are multiple benefits to being fit. There are studies that suggest physical exercising and fitness is beneficial for both younger [18] and older [19] people. One of the ideas behind this master thesis and the FitnessVR App produced for it is to create a product that enables a new way of achieving fitness through exercising.

Fitness, or physical fitness, being defined as a state of health and well-being, the body's ability to function in physical activity [20]. *Exercise* is a structured physical activity. It can be repetitive and its purpose is improvement of physical fitness [21]. Exercises will be a key component in the FitnessVR App. In fact, the entire system will be designed around scenarios in which physical exercising is done.

Along with fitness through exercising, the FitnessVR App will also attempt to see if a general increase in well-being through mindfulness can be added to the app as well. According to Bostock et al. [22], people with a high work stress have demonstrated worse mental and physical health. Bostock et al. also concluded that app-based mindfulness helped to reduce work stress. In this report their definition of mindfulness will be used: "a state in which one is paying full attention to their present moment experience with openness and nonjudgemental acceptance" [22]. van der Pals [23] also suggests that mindfulness and exercising can be good for you.

2.7 3D User Interface

In a VR application utilizing Room-scale VR, the user interface is placed in a 3D space as opposed to the traditional flat 2D computer screen or mobile phone. This presents a few new opportunities and potential problems.

Some of the traditional 2D UI input methods, such as a mouse or keyboard, may prove insufficient for some of the 3D space interactions enabled by a 3D user interface in VR environment. In 3D space, things can exist anywhere along axises and can have any orientation. Things can be located in front of, above, under, to the right, to the left, or even behind the user.

The benefit of a 3D user interface is that many of the interactions can be related to similar interactions in the real world. So the 3D UI could potentially be used intuitively by the user using their natural skills. This can also mean that in a 3D UI has a shorter *cognitive distance* between the user's action and the system's feedback [13]. Picking up a virtual object and placing it upon a virtual table, for an example, could very closely match picking something up and moving in in the real world, thus being and action with a result that the user can easily anticipate and relate to expected behavior from the real world.

However, Bowman et al [13] also suggest that 3D interaction can be difficult to grasp and get right for the user. This is because the 3D environment, while similar in many ways to the real world, lacks many of the cues and affordances and constraints of the real world. Affordances being what the user can do using interaction techniques, and constraints being what they cannot do.

And so, a 3D user interface must be designed very carefully in order to address as many of these subtle differences from the real world as possible.

2.8 User-centered design and evaluation

In creating a 3D user interface that is partially integrated with the virtual world, evaluation of the result is needed. Since the project will seek to explore new venues in combining aspects of separate branches and disciplines, where established best practices are scarce, prototyping and an iterative development and evaluation process will be used. This process will be user-centered, meaning the users are more closely involved throughout the process.

Prototypes are classified based on levels of fidelity. Since meaningful evaluation can be done even with a low-fidelity (lo-fi) prototype, this will be the approach chosen in the beginning of the project. This ensures that no work is wasted on implementing something that will not work or will have to be removed later due to usability or other reasons [13]. It will also likely be easier to change course and redesign based on input at an early stage, since further down the line the system may have gotten so complex that redesign of any one area cascades into affecting everything else. There may also be time constraints, so that catching design flaws early is the only means of having the time to correct them.

And with user-centered design, the development process constantly involves potential end users giving feedback. They're involved all the way from beginning to end, ideal for a project of such exploratory nature.

Chapter 3
Method

This chapter discusses the method used for the development, testing, and data analysis. The project was conducted in one initial phase, two agile development phases, one test phase, and one data analysis and report writing phase.

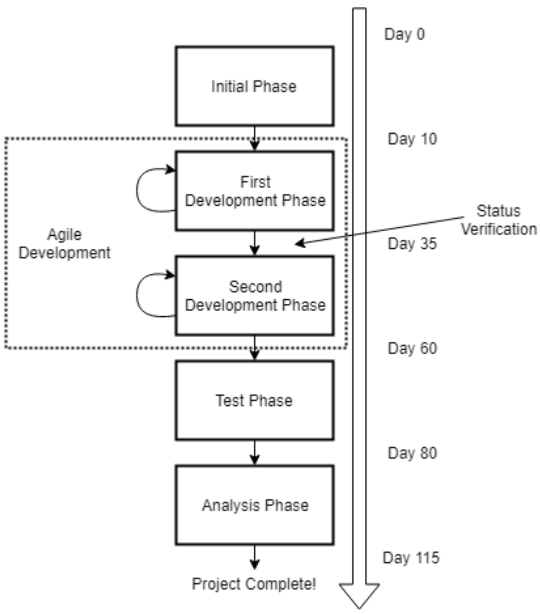

Figure 3.1: Development Process

3.1 Initial Phase

In the initial step, a basic goal was conceived and then elaborated on in a goal document. Various ideas were floated and considered. Then one was picked after consultation with supervisors and stakeholders. Subsequently, a goal document was created and revised a number of times after receiving external feedback. This was done prior to the formal start date of the project.

In the next step, knowledge and scientific material to form a theoretical foundation for the project was collected and accumulated. Books and papers were selected, then studied. As this knowledge was gathered, a rudimentary first draft of the report was being written.

Then some initial prototyping in Unity was done. The prototyping was of lower fidelity and less constrained than what was expected of the final product. This early prototype was showcased to stakeholders of the project and other available university staff to gather feedback and determine the viability of the scope and direction of the project.

3.2 First Development Phase

In this phase, the system was developed with a higher fidelity than in the initial phase, but still focusing more on going breadth rather than depth. Continuous informal testing and observations were done over 5 iterations. During and at the end of this phase, informal user tests were conducted to evaluate the direction of the project and the viability of the application to be useful in the user tests. Feedback was collected and taken into consideration.

3.3 Second Development Phase

In-depth implementation with more heavy integration of theory in the details. Ended with a test-ready product that fulfills the goals and purpose. This phase was about addressing the concerns from the previous phase as well and adding additional functionality and scenarios. Again, informal user tests were conducted during the development, which was against conducted over several smaller iterations. At the end of the second development phase, the application would reach its final state, leaving no more time for development before the user tests commenced.

3.4 Test Phase

The user tests, including the planning and execution of those. During the test phase, a test plan was devised and drafted. Once the test plan was approved, invitations were sent out to a wide range of participants. These participants tested the system, provided some background information about themselves and answered questions. The tests were supervised by the author, who also collected additional data through observations and built-in game mechanics.

3.5 Analysis Phase

After the completion of the test phase, all the collected data was analyzed and placed into data tables and charts. Observations of the results were cross-referenced and compared to theoretical background material. As this process went on, the report was continuously written and expanded with the influx of new information.

Chapter 4
Results

This section contains descriptions and images of the results of the FitnessVR App produced in the development phases, and it includes data tables and charts of the results from the test phase. The full list of features and mechanics implemented is included in the section detailing the Final Prototype.

4.1 First Prototype

Through informal testing and observation of user tests, a few things have been gathered. The observations and tests in the initial phase were informal and ongoing for the entire duration of the phase. Some of the feedback received can be seen in Table 4.1.

Overall, a majority of the people taking part in these informal tests had a positive view of the application. The games were described as fun. The meditation environment and the home lobby were described as visually pleasing to be in.

Table 4.1: Feedback on the first prototype

Feedback
The games begin too abruptly, i.e. the tennis game throwing balls in your face instantly. This caused some test subjects to reflexively jerk back or flinch. Ideas raised in discussions suggested to correct this and to perhaps add in an introduction phase for each game that tells the user what their goal is and what the game mechanics are.
Another things that was brought up was that the various games are too similar. Each game revolved, at this stage, around some sort of ball or object being flung at the player. So it was the feeling of some test persons that the games weren't distinct enough from one another. Suggested ways to correct this was to either modify one of the existing ball-based games or to add a different exercise in the meditation environment.
In discussions and testing with a physiotherapist, it was suggested that a meditation environment (for mindfulness) to be added. This was done, as described in the implementation section, and a new discussion began. It was then brought up that a yoga or stretching exercise could be added to the meditation environment.
It was suggested that the player should be able to bring something with them from the outside, something personal, to bring into the virtual world to use to help motivate them. This could be anything from a personal goal to an inspirational quote.
For better feedback from the games, some users suggested adding sound effects, ambient music, and haptic feedback from the controllers.
Additional comments mentioned the overall lack of incompleteness that plagued the implementation. Certain games had non-user friendly ways to exit back to the home lobby. It was even possible to grab and move certain virtual objects that were not supposed to be moved. This bug, discovered during informal testing, broke key functionality, trapping the user in one scene with no way to return to the home lobby.

4.2 Final Prototype

The final implementation was composed of a Unity-made VR application consisting of six playable activities across 4 scenes (not counting the game setup, which would add one scene and one activity to this count).

4.2.1 Built-in Data Recording

The FitnessVR App records data while being used. The data recorded is time spent, calories burned, repetitions, and failed repetitions done per exercise scenario. It also records the user's overall progress in the form of levels gained. This was implemented to provide more data for understanding how the user uses the system. The data can also be used to investigate whether or not the FitnessVR App is capable of helping the user improve themselves in ways such as having better form during an exercise. To record the amount of calories burned, an average of 0.114 calories per second was selected. This corresponded to low impact exercising for a 155-pound person according to the Harvard Heart Letter [24].

4.2.2 Game Elements of the FitnessVR

In this section is detailed a list of the various UI components and systems that make up the final version of the implemented FitnessVR App.

- **Setup Scene** - A scene where the player picks their dominant and and selects a quote they find inspiring.
- **Home Hub Scene** - A scene which resembles a living room. This is the hub from which all exercises are selected, and to where to the player always returns.
- **Quote Painting** - A painting in the Home Hub that displays the quote that the player selected in the Setup Scene.
- **Instruction Laptop** - A virtual laptop with a set of instructions that the player can follow.
- **Exercise Table** - A TV table upon which rests interactable items that can transport the player to the exercises.
- **Stats Screen** - A giant TV on the wall of the Home Hub. This TV displays total repetitions, calories burned, and time spent exercising. It also displays player level and experience points. The data on this screen comprise the Point System.
- **Points System** - The Points System is the mechanic of recording calories burned, time spent, and repetitions done by the player. It also awards experience points for each player action during exercises, allowing the player to gain levels when an experience point threshold is passed.
- **Trophy Shelf** - A shelf in the Home Hub where trophies are placed after the player completes exercises.
- **Meditation Environment Scene** - An outdoor environment where players can meditate, be mindful, do yoga, and shoot with bow and arrows. The wind blows in the trees, birds can be heard chirping, and animals roam in the woods.
- **Meditation Plaza** - An elevated plaza above the beach in the Meditation Environment. Has its own Teleport Point.
- **Yoga Book** - The yoga book is an interactable book that, when clicked, starts the Yoga Exercise.
- **Bow** - A bow that can be picked up using a Grab Interaction.
- **Meditation Beach** - A different vantage point in the Meditation Environment.
- **Tennis Scene** - The room of the Tennis Exercise, where tennis balls are shot at the player, who can redirect them with a tennis racket in their hand to hit targets on the walls. A scoreboard updates the score. There is also visual, auditory, and haptic feedback.

- **Tennis Targets** - Targets on the walls of the tennis room that give different amounts of points if the player hits them with the tennis balls.

- **Tennis Scoreboard** - A scoreboard showing the current points received in the Tennis Exercise.

- **Squat Attack Scene** - The scene of the Squat Attack Exercise, where balls fly high and low toward the player, who must reach both high and low to smash the balls with their hands to gain points. Music plays in the background and sound and visual effects are used to highlight player interaction and performance.

- **Dodgeball Scene** - The scene of the Dodgeball Execise, where players must move sideways and hide behind crates to avoid balls being thrown at them, all while also attempting to throw balls back at the enemy sphere that flies around.

- **Points System** - A general system permeating the whole game where points are received for performing actions, resulting in gained experience points and levels.

- **Trophies** - Physical trophies are added to the Trophy Shelf of the Home Hub Scene when players do an exercise.

- **Teleportation Interaction** - By holding down the Teleport Button, players can see teleport points, and by then aiming at them with a beam from out of their hand controller and releasing the button, they are teleported to that point.

- **Laser Pointer Interaction** - Sometime a laser beam is emitted from one of the player's virtual hands. Pointing at an object with this laser pointer and then pressing the Trigger Button will trigger that object (if it is interactable).

- **Grab Interaction** - The player moves their hand to certain interactable objects and holds down the Trigger Button. The object is then attached to the hand, only released when the Trigger Button is released, simulating grabbing the object.

- **Push Interaction** - Some scenes feature a button where the player simply moves their hand down toward a button, causing it to be pushed down and activated.

Next are a set of images (Figures 4.1 to 4.6), each displaying one of the six scenes the participants could visit during their test of the FitnessVR App.

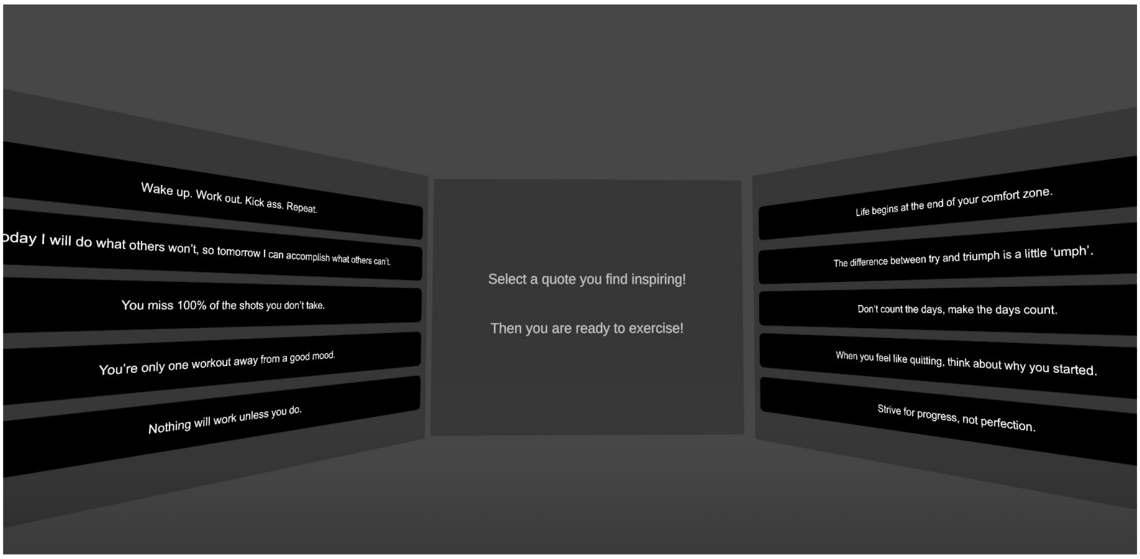

Figure 4.1: The Setup Scene

Figure 4.2: The Home Hub Scene, showing also the Stats Screen, Instruction Laptop, Exercise Table, and Trophy Shelf

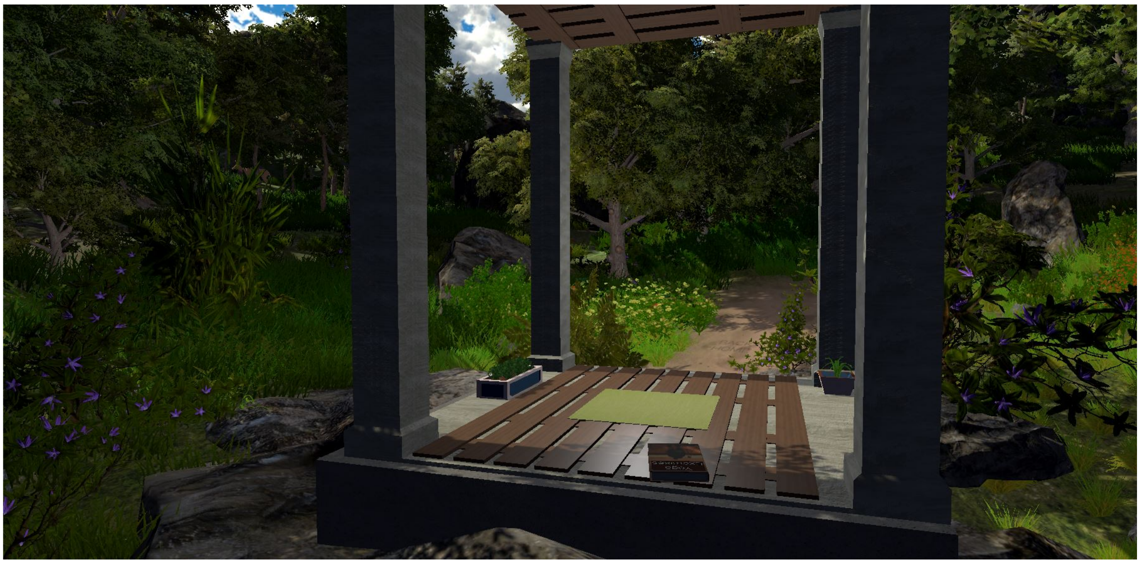

Figure 4.3: The Meditation Environment Scene, showing the Meditation Plaza and Yoga Book

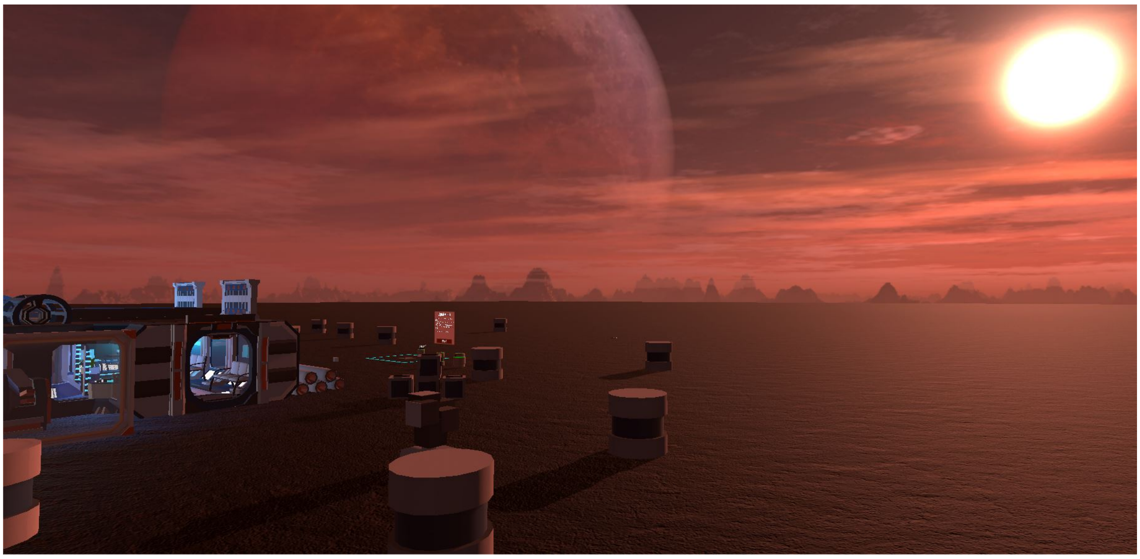

Figure 4.4: The Squat Attack Scene

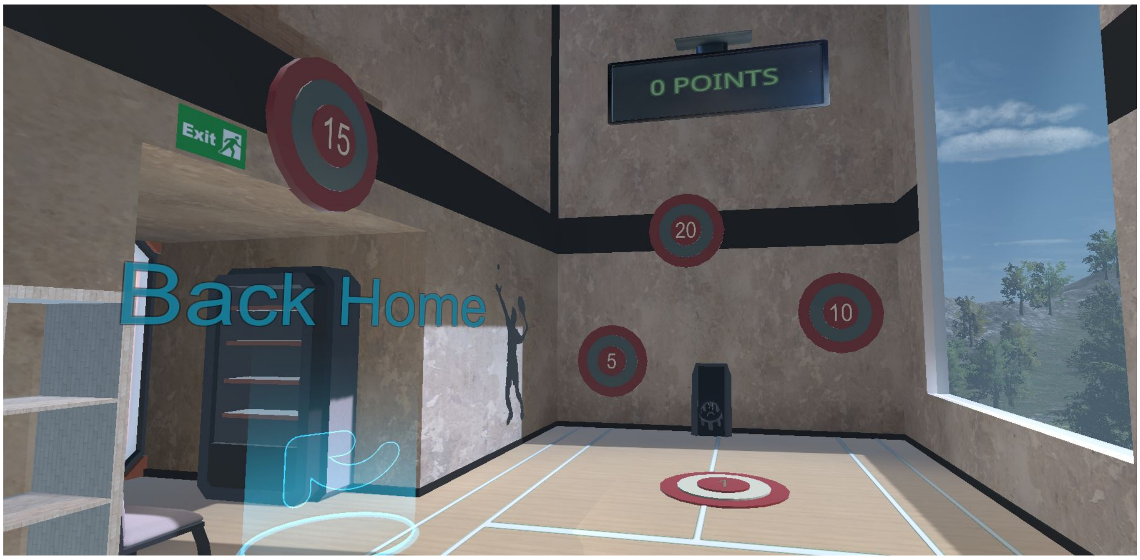

Figure 4.5: The Tennis Scene, showing Tennis Targets and Scoreboard, and an active Teleportation Interaction point

Figure 4.6: The Dodgeball Scene

4.3 User Tests

In this section, the master thesis author is referred to in their role as the *test leader*. The people invited to do the tests are referred to as *test participants* or simply *participants*.

The test introduction and VR introduction templates can be found in Appendix A. The user consent form filled by the participants prior to the test was taken from Usability.gov and was modified to more accurately reflect the specific test the participant was about to embark on [25]. The test sessions were structured according to Figure 4.7.

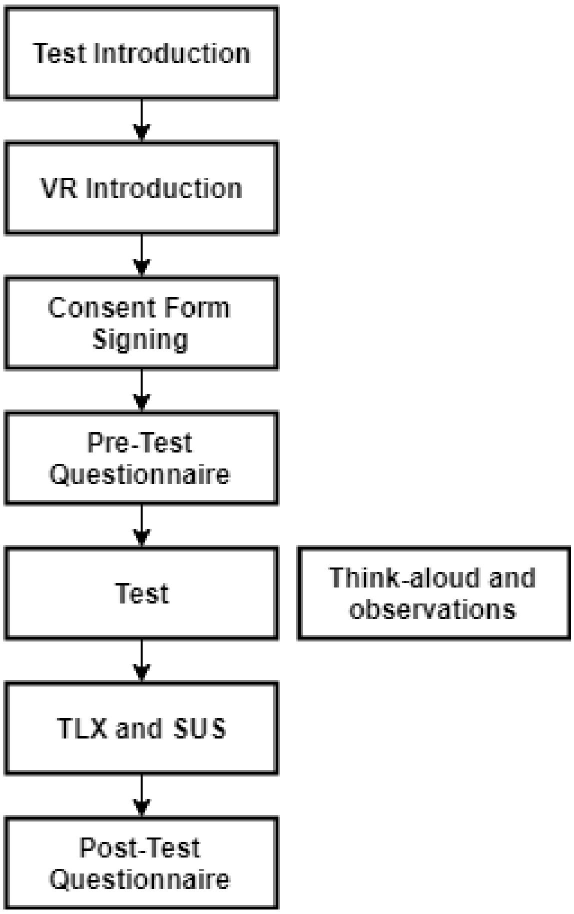

Figure 4.7: Structure of the user test

4.3.1 Test Material

Pre-test Questionnaires

The Pre-Test Questionnare filled in by the users before the beginning of the test can be seen in the table of Figure 4.2.

Table 4.2: The questions of the pre-test questionnaire form filled by the participants.

Question	**Measurement**
Gender	Male, Female, Other
Age	[Number]
How often do you exercise or engage in fitness activities (weight lifting, running, cardio, sports, etc.)?	Never, A few times per month, 1-2 times/week, 3-4 times/week, 5+ times/week
What is your experience level with Virtual Reality (VR)?	No experience at all, Low, Moderate, High
What is your general experience level with computer games?	No experience at all, Low, Moderate, High
Have you tried an earlier version of the "Fitness and Exercising in Virtual Reality" application?	Yes, No

Post-test Interviews/Questionnaire

The Post-Test Questionnaire filled in by the users before the beginning of the test can be seen in the table of Figure 4.3. In this questionnaire the answers were more free-form and the test participants were allowed to answer and elaborate in their own words. The answers were verbally communicated by the participant and recorded in text by the test leader.

Table 4.3: The questions of the post-test questionnaire form filled by the participants.

Question
Did you feel immersed in the game? I.e. did you become engaged, did you forget about the outside world, and did you feel like a part of the virtual world?
How did the 3D user interface feel? Better or worse than a traditional flat 2D UI? Any advantages/disadvantages to integrate user interactions into the virtual 3D world?
Did the game help motivate you to continue in any way?
Did you feel a sense of progress? Did you get anywhere with your training?
From what you experienced here, do you think it is possible to improve fitness with physical exercising in a virtual reality app?
Does VR training provide any advantages to ordinary exercising? Or does it present any obstacles?
Did you feel nausea during any part of the virtual reality experience? Or after it?

The results of the data collected from these questions are presented in the User Test Participants section.

4.3.2 User Test Participants

For the participant selection process for the user tests, a number of approaches were used to get variety in the base of participant. Friends and fellow students of the author were one of the subgroups invited. The second subgroup consisted of usually older participants, many with no engineering background. They were invited through colleagues and the parents of the author. This gave a range of different participants with various levels of proficiency with VR, gaming and physical exercising. A total of 21 users participated in the formal users tests. General data about the test participants was recorded in the Pre-Test Questionnaire (Table 4.2), and the results can be seen in Figures 4.8 to 4.13.

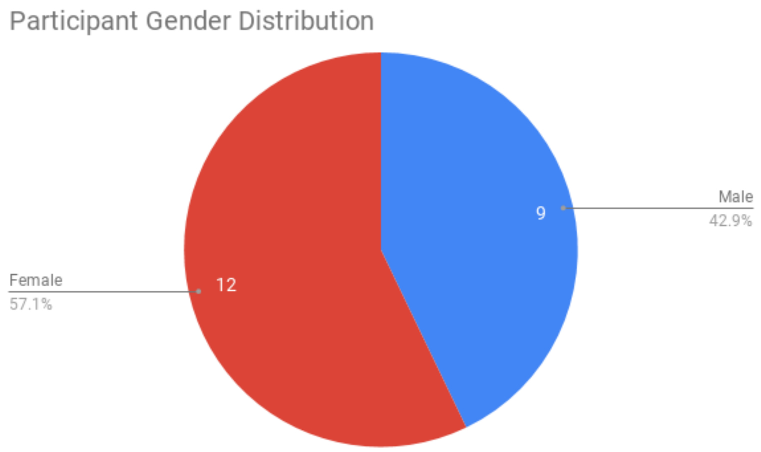

Figure 4.8: Participant Gender Distribution

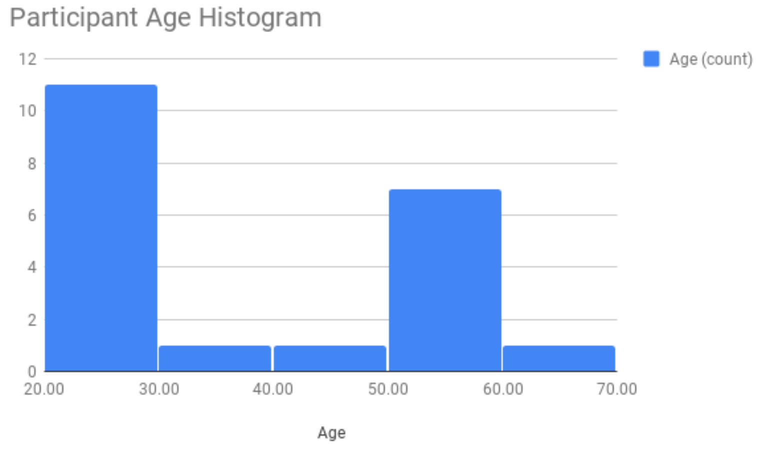

Figure 4.9: Participant Age Histogram

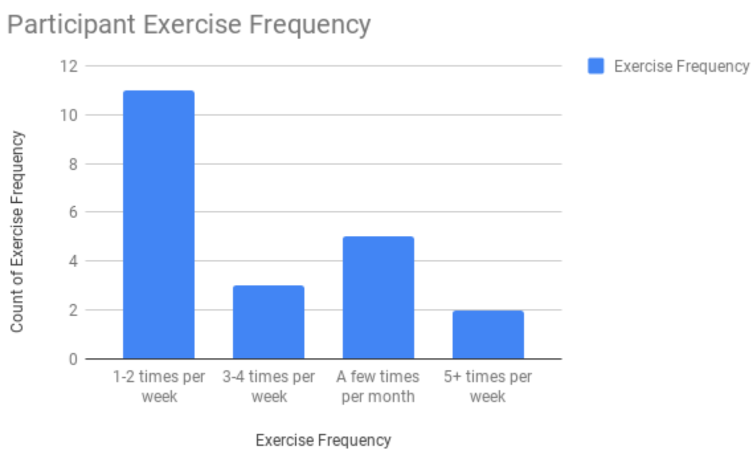

Figure 4.10: Participant Exercise Frequency

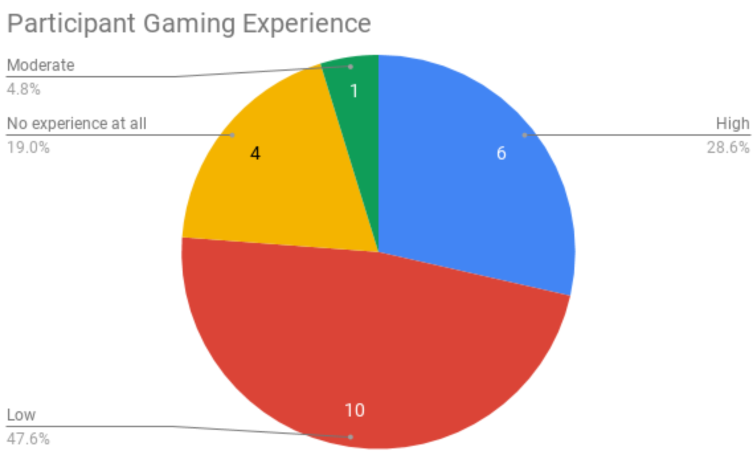

Figure 4.11: Participant Gaming Experience

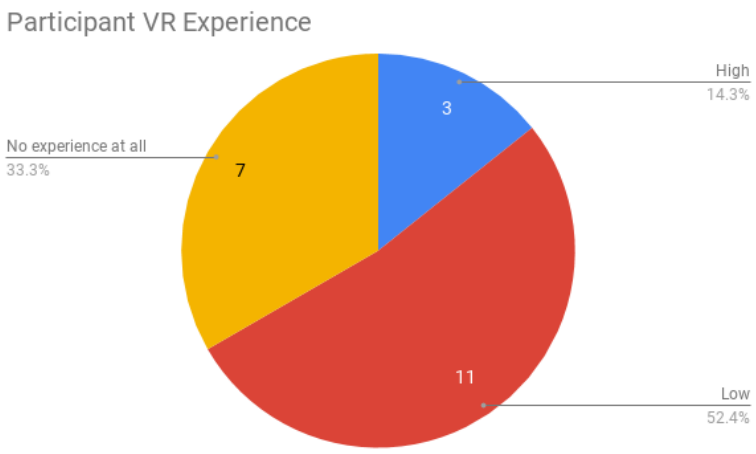

Figure 4.12: Participant VR Experience

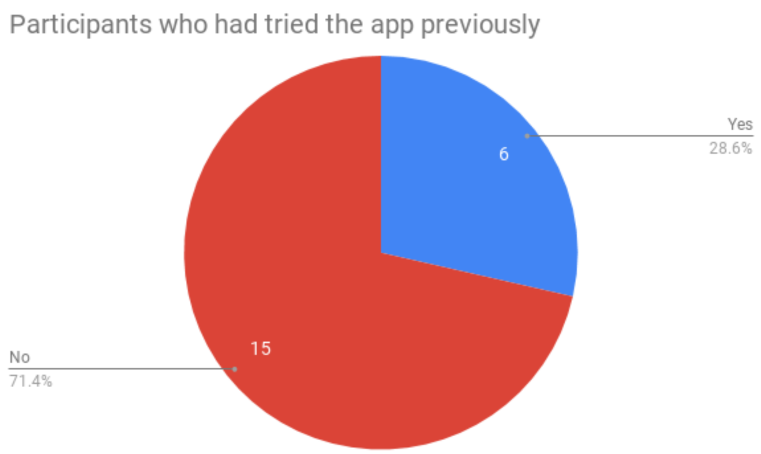

Figure 4.13: Participants who had tried the app previously

4.3.3 Results of Collected Data

Data was also collected to determine the total time spent by participants in the different exercise scenarios of the FitnessVR App (Figure 4.14). The data is grouped by the participants' level of gaming experience. Additionally, the data is displayed twice, but in the one instance all participants who exercise only a few times per month have been filtered away. In the filtered data, all groups spent more time in the exercises. In both the filtered and the unfiltered data, the group with moderate gaming experience spent the most time in the exercises, and the group with the highest gaming experience spent the least time.

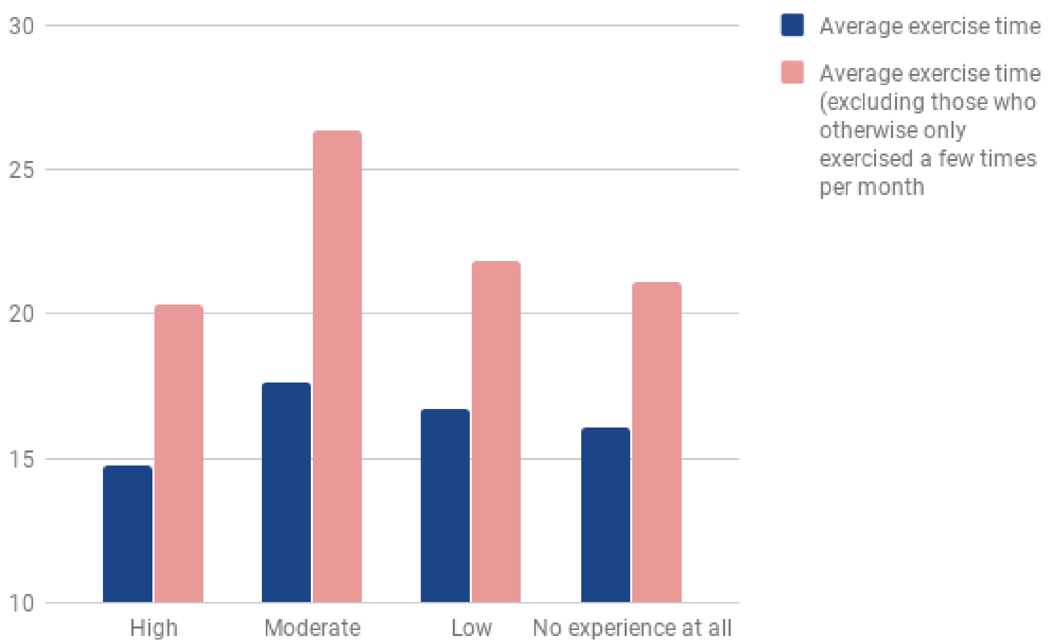

Figure 4.14: Time spent exercising divided by gaming experience and filtered by usual exercise frequency

Here (Figure 4.15), the average total repetitions done over all the exercises are shown. The data is grouped by gaming experience. The users with low prior gaming experience did more repetitions on average than any of the other groups.

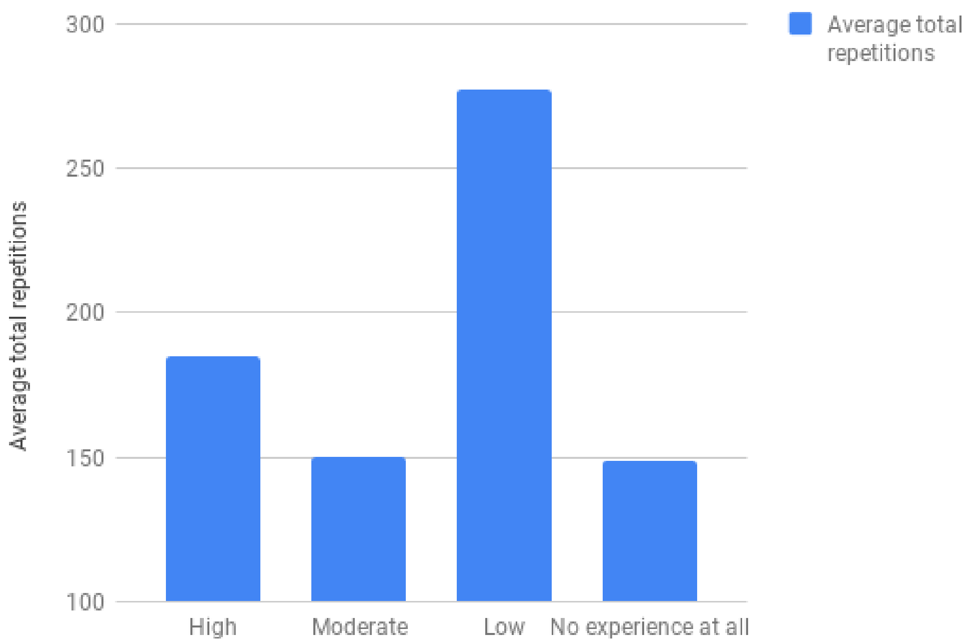

Figure 4.15: Total number of repetitions done, grouped by gaming experience

The results of the question *"Did the participants confuse the Trigger Button with the Teleport Button"* are shown in Figure 4.16. The results are grouped by VR experience. These results were recorded by observing if the participant attempted to use the Teleport Button to perform an interaction that was designed for the Trigger Button, and vice versa. *No* means that there was no such confusion at all. *Yes* means that the participant used the wrong button at least once when performing such an interaction. *Slightly* is similar to *yes*, but differs because the participant almost instantly interacted again using the proper button. There is a somewhat even distribution of yes and no answers across all groups.

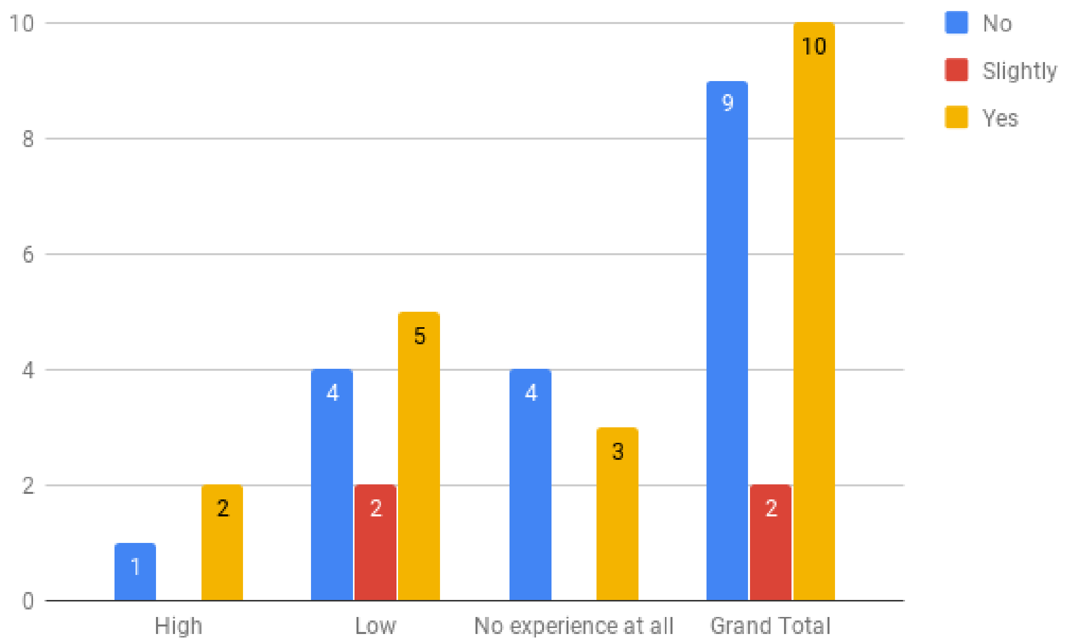

Figure 4.16: Confusing the Trigger and Teleport buttons

Figure 4.17 shows whether or not the participants were able to use the teleport function. The results are grouped by VR experience. *Yes* means that they were able to use the teleport function, *no* means that they weren't able without help from the test supervisor, and *with difficulty* means they were able to do it on their own but only after trying and failing for a while first. Being able to use the teleport function was the most common, but almost one third of the participants required help from the test supervisor.

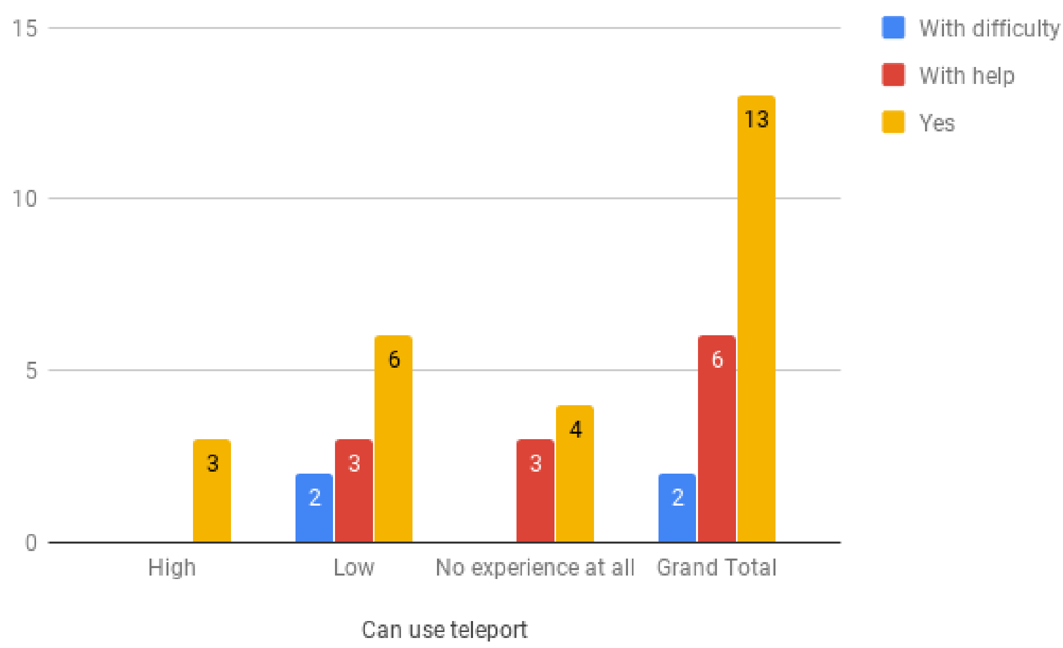

Figure 4.17: Could the participants use the teleport function?

Another thing that was observed was whether or whether not the participant searched for interaction in the VR environment (Figure 4.18). Search for interaction means that they attempted click on and touch various objects in their environment, sometimes approaching objects that they expected to be interactable (things in bookshelves, a smartphone on a table, etc.).

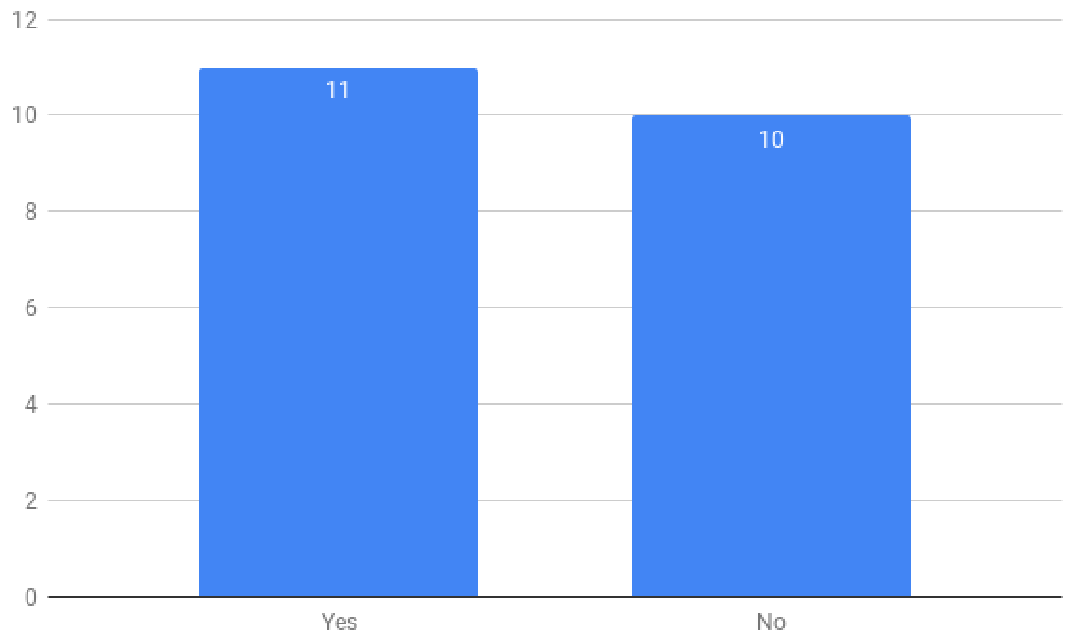

Figure 4.18: Did the participants search for interaction?

Gamification Results

Gamification is one of the major areas investigated by this thesis. How well this was integrated into the FitnessVR App was measured by asking and observing what motivated the users as well as what gave them a sense of progress.

Table 4.4 shows the different things that participants said motivated them while using the FitnessVR App. The results in this table were collected during the Post-Test Questionnaire (Table 4.3). Some motivating factors appear on multiple rows. This is so that the data can illustrate whether certain factors appears lumped together with others as the participants describe what motivates them. The results are also grouped by the participants' gaming experience.

Table 4.4: Number of participants that found different things motivating, grouped by gaming experience (from no experience to high).

	High	Moderate	Low	No experience	Sum
Audio	1				1
Audio, Trophies	1				1
Feedback			1		1
Feedback, Audio				1	1
Game			4	1	5
Learning			1		1
Nothing			1		1
Points	2				2
Points, Audio, VR				1	1
Points, Feedback			1		1
Points, Game	1				1
Points, Trophies		1			1
VR	1		2	1	4

Table 4.5 shows the answers of the test participants from the Post-Test Questionnaire (Table 4.3) when asked about what gave them a sense of progress. *Stats* refers to the explicitly shown statistics relating to participant performance in the FitnessVR App (calories burned, time spent, repetitions done, etc.). These stats was displayed on the Stats Screen in the Home Hub Scene and on the Scoreboard in the Tennis Scene.

Table 4.5: Things that participants reported as giving them a sense of progress. Results grouped by gaming experience.

	High	Moderate	Low	No experience	Total
Learning			2	1	3
Stats	3		4	1	8
Stats, Trophies	2				2
Getting sweaty				1	1
Too distracted to think about progress			1		1
Nothing. Goals were unclear.	1				1
Nothing		1	3	1	5

The Stats Screen in the Home Hub Scene (4.2) shows the user the points and progress they have amassed while exercising. Figure 4.19 shows whether or whether not the participants noticed the Stats Screen. The results are grouped by gaming experience. All of the participants with high gaming experience noticed the Stats Screen. Half of the participants with no or low gaming experience did not take notice of it.

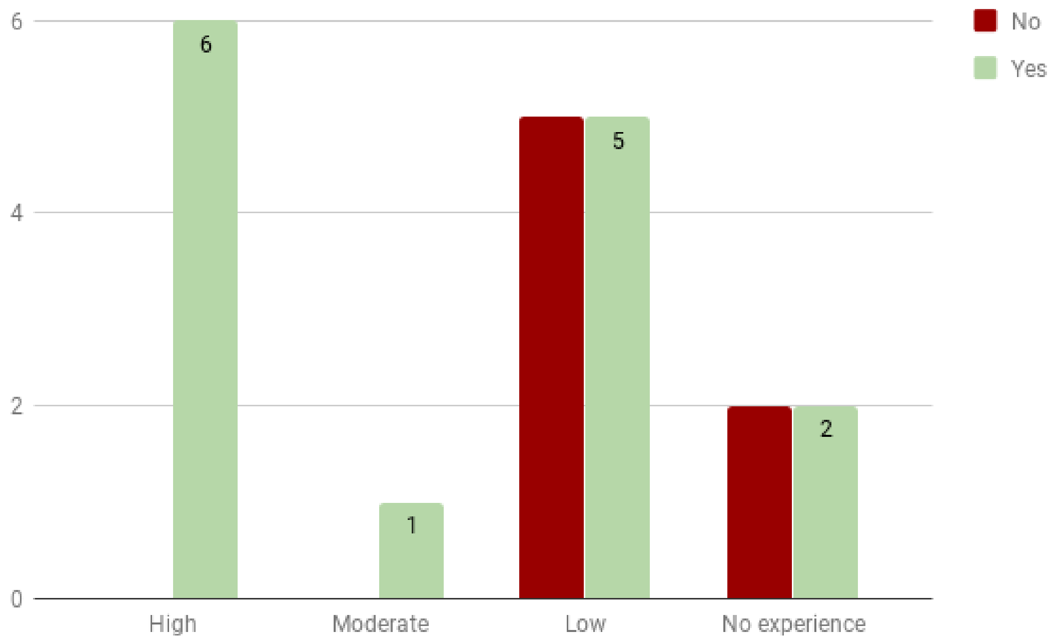

Figure 4.19: The number of participants that noticed that Stats Screen and the number that didn't. Data is grouped by participant gaming experience (ranging from no experience to high).

Observations relating to the hardware

Nine participants reported no problems at all relating to the hardware. Twelve participants reported various distractions and discomforts relating to the hardware, ranging from a dirty HMD lens and low display resolution to hitting the wall with a hand controller and commenting that there was nothing to display the position of their feet. This data can be seen in Figure 4.20. *"Yes (ground)"* means that the participant felt it was strange to stand on flat ground in the real world while in the VR world they stood on a slope.

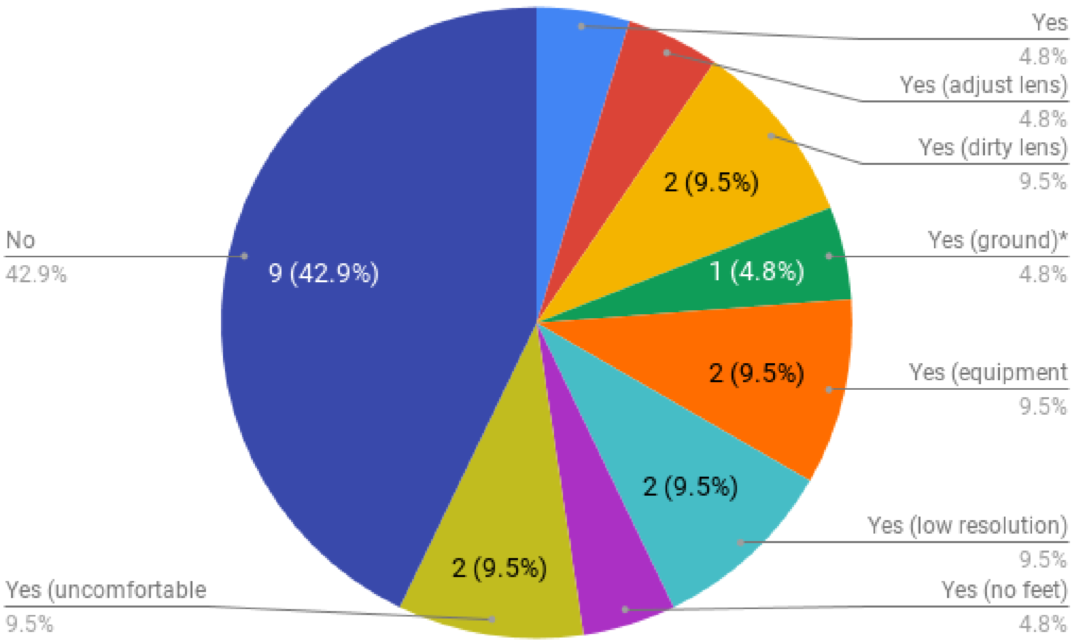

Figure 4.20: Types of problems reported relating to the hardware.

Game Data Divided by Exercise Scenarios

Figures 4.21, 4.23 and 4.22 show the amount of time (in minutes) spent and the number of repetitions and failed repetitions (fails) done in each exercise. Dodgeball shows zero repetitions because of a technical issue making it almost completely impossible to register a successful repetition. Also because of a technical problem that was not caught until testing was underway, fails in Dodgeball (being hit by a ball) did not register. In Yoga it is impossible to fail, hence zero fails there.

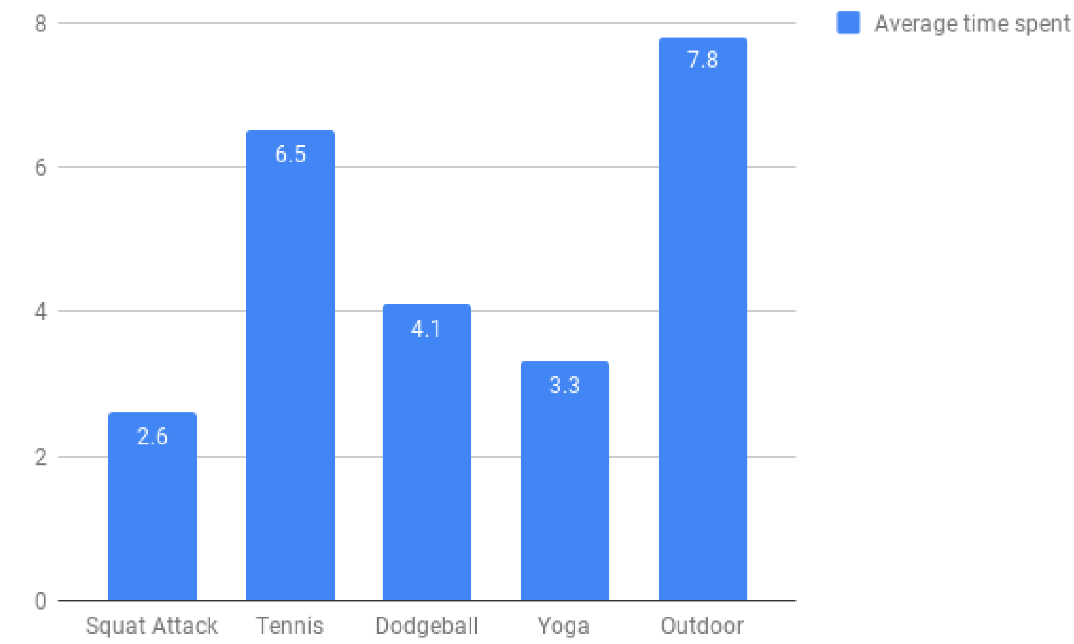

Figure 4.21: Average time (minutes) spent in each exercise.

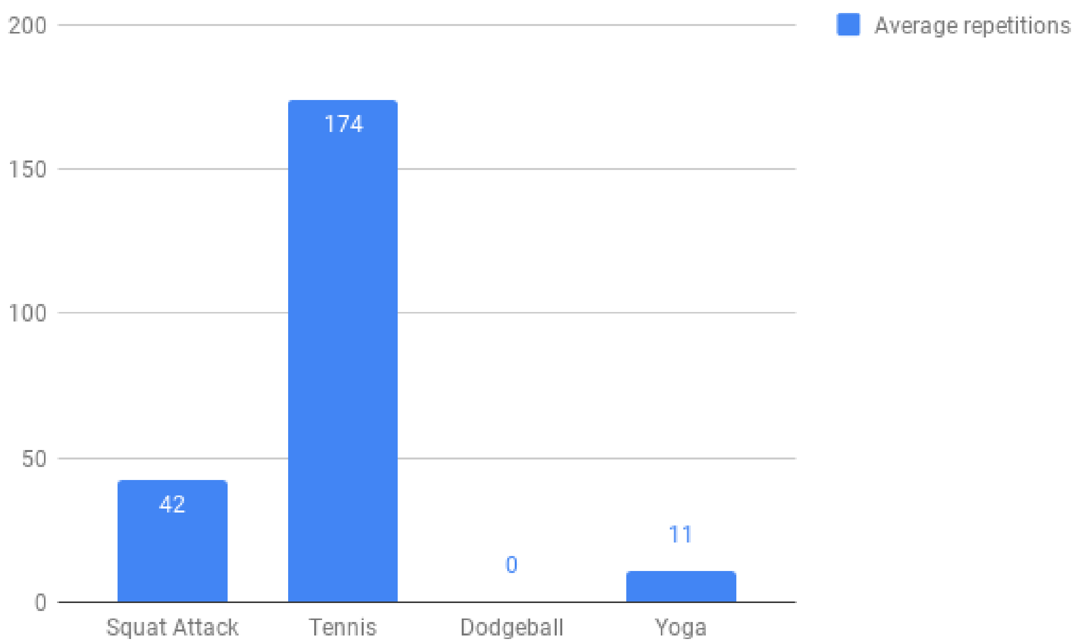

Figure 4.22: Average repetitions done in each exercise.

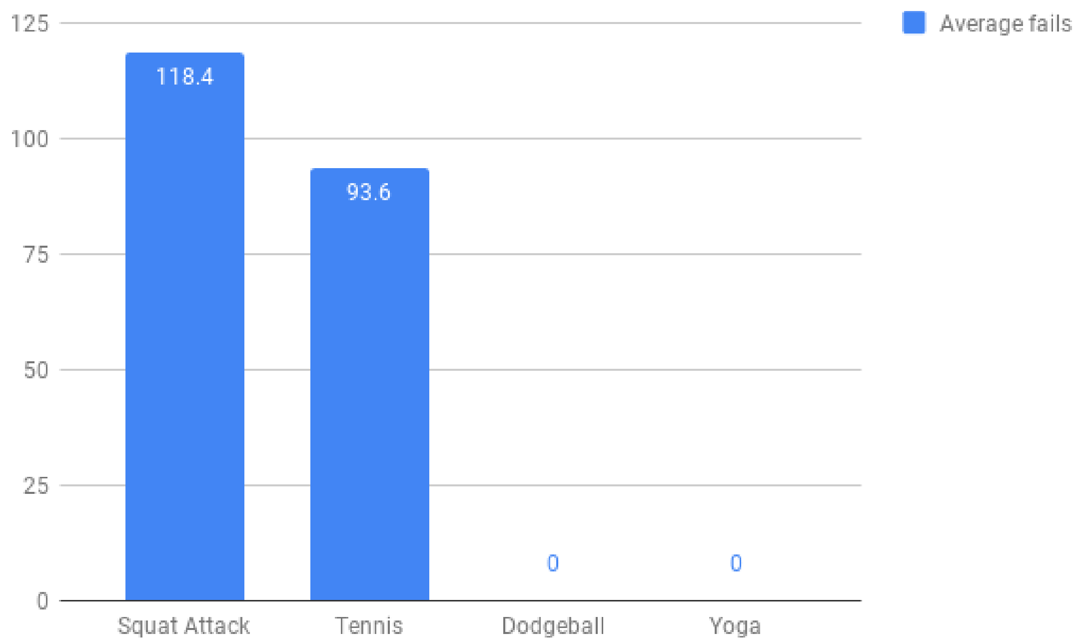

Figure 4.23: Average fails done in each exercise.

4.3.4 Results of what the users think

User opinion on the FitnessVR App was collected through NASA TLX, SUS, interview questions, and through participants "thinking out loud" as the test progressed.

SUS and NASA-TLX

The results of the SUS survey shows that the users rated the FitnessVR App with a score of 76.9. This score is above 68, which, according to Usability.gov [25], is above average.

Figure 4.24 shows the results of the NASA-TLX survey. The lowest rated measurements are Temporal Demand (40) and Frustration (25), with all others ratings sticking around 50-60.

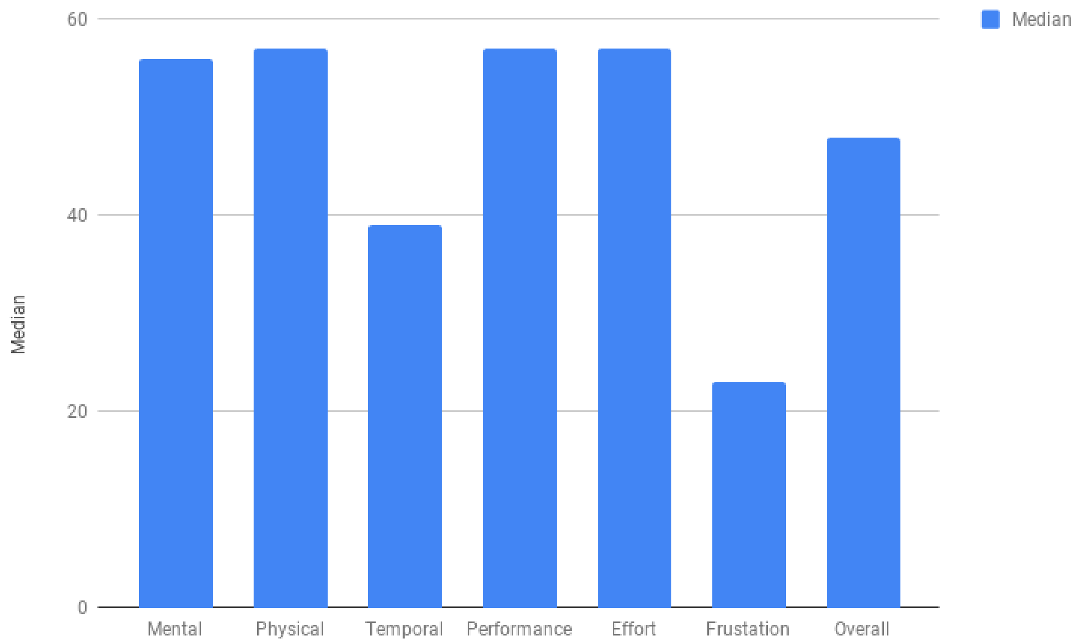

Figure 4.24: The results collected from the NASA-TLX survey.

Immersion

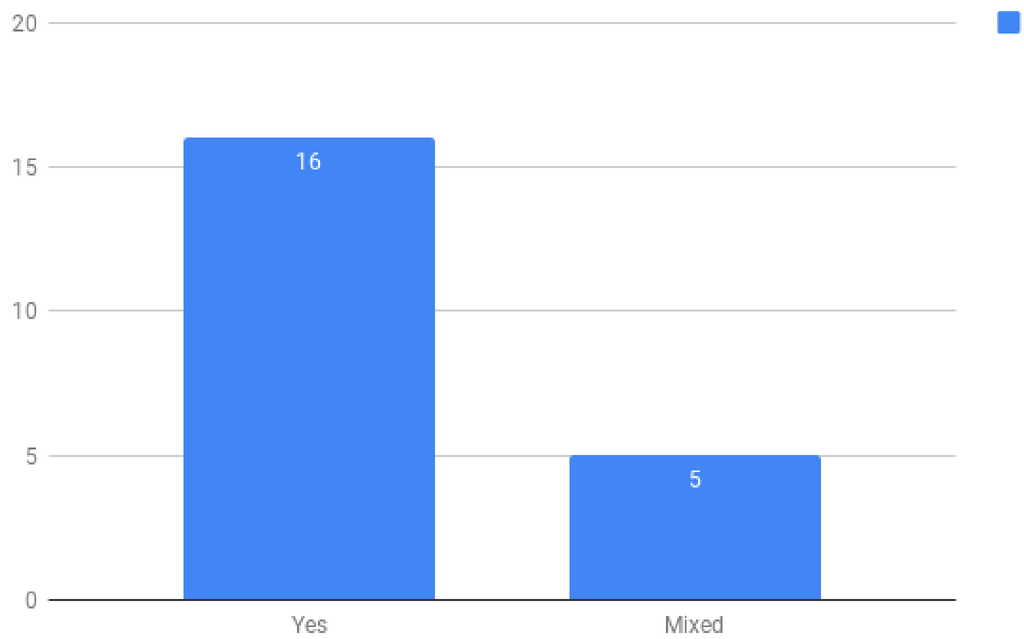

Figure 4.25: Participant sense of immersion.

Figure 4.26 shows what the participants thought about the physics in the Tennis Scene. 10 participants reported no problems at all. One participant felt that the physics were bad and

5 participants had mixed feelings about the physics. In addition, five more participants did not explicitly say anything about the physics. Because test supervisor built the FitnessVR App, it was possible to observe when a user attempted an action in the Tennis Scene but failed due to physics, despite them not knowing the reason for their failure. Some of these participants, found under the label *Indirectly* in Figure 4.26, did make comments when they failed an action during the exercise, but they attributed it to their own skill level or that they hadn't had the time to learn how the game works yet.

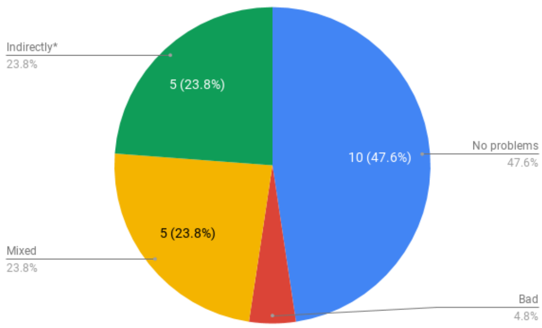

Figure 4.26: Participant opinion on the physics in the Tennis Scene

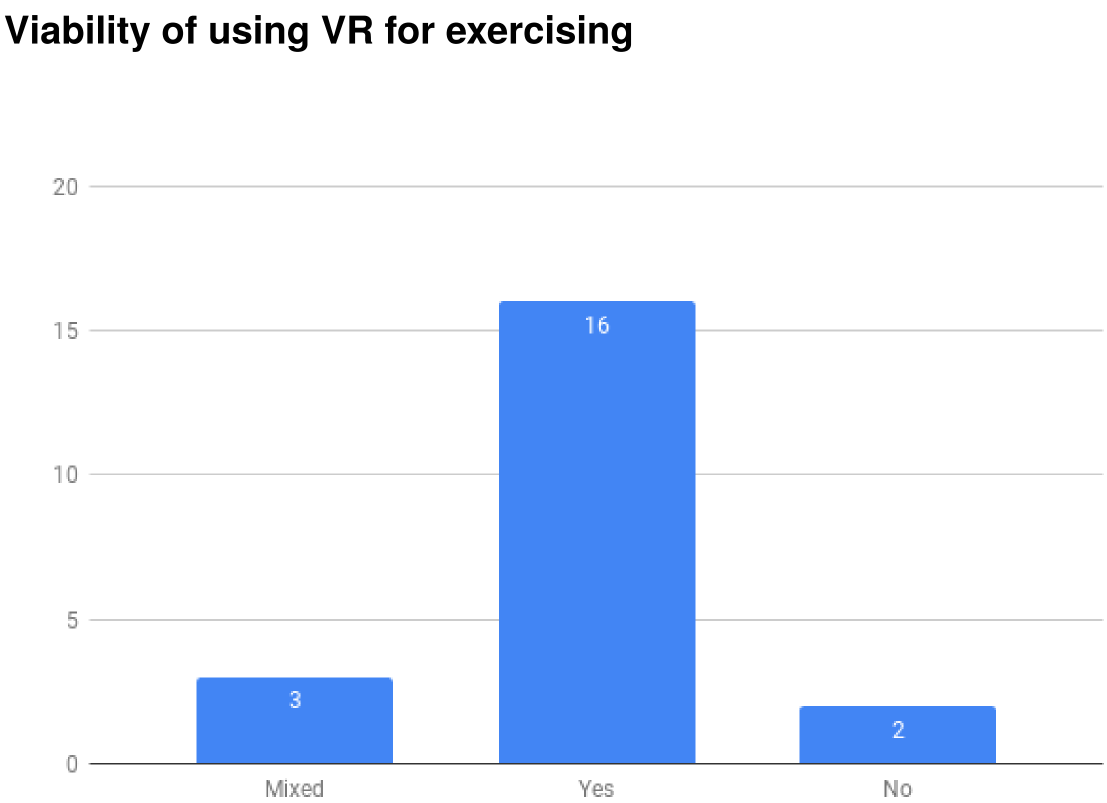

Figure 4.27: Participant opinion on the viability of using VR for exercising.

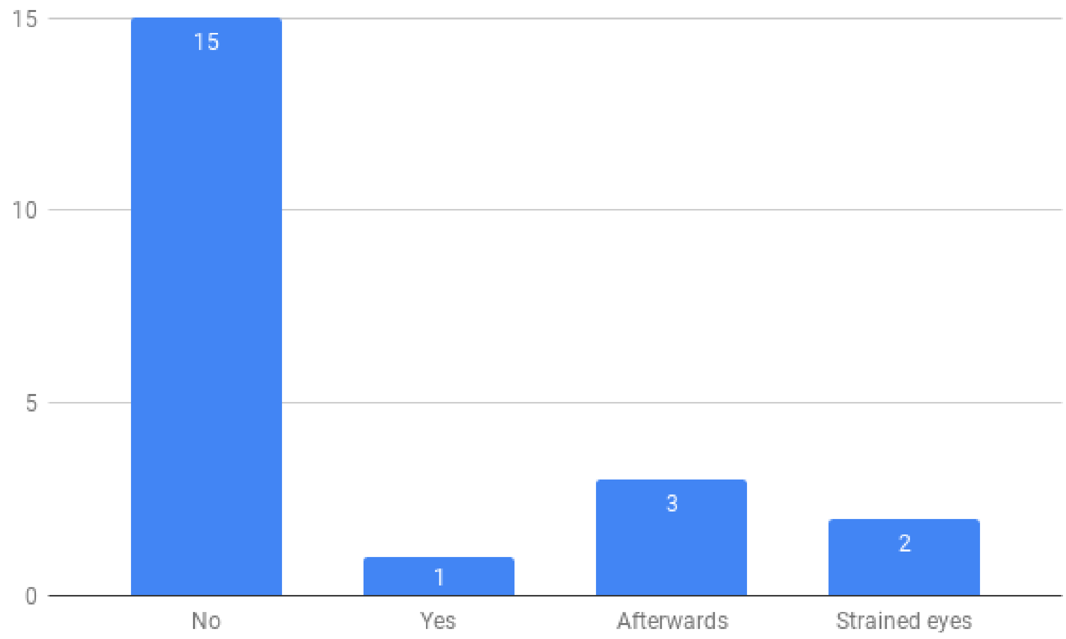

Figure 4.28: Participant sense of discomfort using VR equipment, answering the question whether they felt discomfort and how.

Participant opinions on using a 3D user interface

Table 4.6 shows the various opinions expressed by the participants when asked about what their opinion on using a 3D user interface as opposed to a traditional flat UI was.

Table 4.6: Participant opinions on using a 3D user interface (paraphrased for readability).

Participant comments
More immersive, but also difficult to know what to do.
Too many 2D UI elements.
Perfect for a fitness app to move around to interact. But how do you know what you can interact with? You risk missing things.
Fun. Not as tiring as looking on a flat screen.
It felt natural and it was good that it didn't require fine motor precision skills.
It's good to move around to interact when it is a fitness app.
Immersive
Felt natural.
New and exciting. But you risk missing things.
Good. But you don't always know what to do and risk missing things.
Not completely intuitive.
Immersive.
Easy.

Chapter 5
Discussion

In this section will be discussed the development process used to create the FitnessVR App and results of the subsequent user tests.

5.1 Development and Design Choices

This section discusses the design choices made during the development of the FitnessVR App. Gamification, VR, and fitness are the three major ideas forming the central pillar of this work. A number of choices were made in the development process with the intent of merging these together to create a better whole.

5.1.1 Choice of hardware and software

The HTC Vive was chosen due to its superior room-tracking capabilities and good integration with the Unity game engine. It is also a system with which the project author had prior experience. It is also one of the better and more popular VR headsets on the market. The choice of using hand controllers over VR gloves is debatable, because the user can't move their hands as freely. That seems counter-productive for a physical exercising app. However, it was decided that familiar and more proven equipment would be used to reduce the risk of unexpected problems that could halt development.

Unity was chosen over other game engines like Unreal Engine because of its extensive asset marketplace and its integration with HTC Vive hardware.

5.1.2 Fun exercising

During development, one of the ideas was to motivate the user to exercise by making the FitnessVR App fun compared to just exercising as usual. This was something mentioned by Deterding et al. [15]. That sense of fun should come from, but not necessarily be limited to, a gamification of the activities performed by the user. The idea being that the fun, augmented by immersion and presence in the VR scenario, would hopefully mask the potential boredom of performing the exercising, letting the user have fun while working toward their goal. For an example, in the Squat Attack Scenario the environment was designed to look like an alien planet with music playing in the background. This was to make the situation more fun and to perhaps engage the player on more than just a utilitarian level. With this fun and increased motivation, the hope was that the user would exercise more and not think too much about the boring and exhausting aspects of the exercise.

5.1.3 Choice of exercise scenarios

Choosing which exercises to implement and include in the FitnessVR App was largely constrained by the time frame of the project and the limitations of the VR hardware. The idea was to try to pick exercises that utilized the room-scale VR both vertically and horizontally, and to make sure the exercises did not require anything more than large, rudimentary hand and arm movements.

The addition of the bow was motivated by early user feedback pointing out that all the exercises were related to ball games. The bow and arrows did not have that. It also allowed the user to use the bow at their own pace and it introduced an element of a static exercise. Holding the arm up in the air while wielding the bow would supposedly require a bit of an effort after a while, which was also confirmed by some comments by test participants in test phase.

Some exercises like push ups were considered for implementation, but were eliminated due to being unwieldy to do when wearing VR equipment.

5.1.4 Points System and Trophies

The Point System of general experience points for leveling up, and the user data such as repetitions and time spent exercising, was chosen to satisfy two major underlying theories of this project. Firstly, similar systems are used in video games. Seeing game mechanics where players level up or gain points is quite common. So the inclusion of this system in the project satisfied a big expectation of what a gamified app is. It is also a proven concept in the game industry. Secondly, the Points System satisfies the need to translate future benefits of taking an action into something real in the present [9]. The benefit of physical exercise is not immediate, but appears weeks or even months later. The points system represents the effort put in by the player using numbers. This enables them to get a more immediate sense and proof of progress every bit along the way. Positive aspects of the user's performance during the exercising that may otherwise have gone unnoticed will be highlighted.

The trophy system, which gave the player trophy rewards for every exercising scenario they tried, was also implemented to augment this effect.

5.2 User Tests Discussion

Om discussing the results of the user tests, some data have been marked as more important. This is data relating to the total time spent in the system, since when execising the time spent doing it is important. It is also data relating to the motivation of the user and whether or whether not the gamified mechanics of the app had any effect. Data relating to the general use of the 3D user interface is also important because this the means through which all interaction with the system happens.

5.2.1 General Use of the FitnessVR App

Some general observations can be made about the test sessions. First off, the participants gave the FitnessVR App an average score of 76.9 in the SUS survey. As indicated by Usability.gov [25], this is an above average score. A majority also thought fitness through VR was a viable idea (Figure 4.27). Combine this with the comments recorded in Table 4.6 and it seems that the general consensus is that an idea like this works. But there were concerns, so an updated version of the FitnessVR App should probably be more clear when it comes to what you can do and what your immediate goal is.

Looking at the results of the NASA-TLX (Figure 4.24), the physical demand wasn't rated much higher than anything else. This was a bit surprising and contrary to the intention. The FitnessVR App should be physically demanding. Yet here, physical demand was rated similarly to mental demand. This again supports the idea that the app needs to be more clear with what's going on. Judging by the physical demand rating, the exercises should be reworked to be more physically demanding as well.

Participants also rated their frustration level rather low in the NASA-TLX, however. This is good, because it appears that despite the app's shortcomings, it did not bother the participants too much. Frustration is the opposite of what this app hopes to trigger. Had the participants become too frustrated, it may even be possible that they had not thought the idea to be viable at all.

5.2.2 3D interaction in VR

In the results, in Figures 4.17 and 4.16, it is shown that about half of the test participants at some point or another confused the Trigger Button with the Teleport Button. This can be because of several reasons. First, they are both buttons that you click on the Hand Controller. Second, the Trigger Button is used, in a sense, to teleport into the different exercise scenes by aiming with the Laser Pointer at the Exercise Table and clicking the Trigger Button. This makes the two interactions both physically and conceptually similar. It can be worth noting, however, that a larger percentage of the users figured out the difference anyway and managed to use both interactions properly. So even if there is some confusion and some attempts to interact using the wrong button, two thirds still managed to use both interactions properly in the end. Most of those who couldn't figure out the Teleport Button still managed to get it with some hints from the test supervisor.

It also seems likely that the Teleport Interactions are more conceptually difficult than the Laser Pointer interactions using the Trigger Button. With the Laser Pointer, you aim and click. With the Teleporter you click, hold down, aim, then release.

Regarding teleportation in general, I think it is the right choice to include it. Other forms of moving around outside the boundaries of the play area come with the risk of causing nausea and discomfort when the senses of the body do not agree on what is happening [26]. As indicated by the results (Figure 4.28), the FitnessVR App as it was implemented did not cause any significant nausea or discomfort.

Interacting in VR versus the real world

As stated by Bowman et al [13], interaction in a 3D UI can be difficult due to the lack of cues, affordances and constraints which are found in the real world. So, the 3D world may either lack some aspects of the real world or it does something differently, which makes things more difficult for the user. This was observed to some extent.

While wielding a laser pointer in one hand, several users tried to pick up balls in the dodgeball game by clicking on them with the laser pointer. Since this was the mode of interaction they had previously used in the FitnessVR App, it is likely that they expected to continue using that way of interacting. Additionally, in contrast to the real world, in the virtual dodgeball environment the user had no hands (but hand controls instead) and a constantly present laser pointer. Lastly, instead of actually grasping something with their hand, the user instead clicks a button using only one finger in order to simulate a grasping interaction in the system.

None of this corresponds to a usual situation in the real world. Hence, these users did not think to pick up the balls like they would in the real world. This is in spite of the fact that the intention was that the user should pick up the balls by physically moving their hand to it and performing the grasping interaction. This observation seems to be in support of the theory that subtle differences from the real world cause a breakdown of the understanding of and proficiency with the system's interactions [13].

Since one of the goals of the project was to create immersion and intuitive interaction in VR, these results point to a failing in the design. Possible fixes could have been to replace the hand controller visuals with virtual hands (this was originally intended, but had to be cut due to technical difficulties), removing the laser pointer when it was no longer needed, and using VR gloves instead of hand controllers. To stress, this points toward the importance of paying attention to the small details and to make sure that the system does not give the user the wrong cues about the conceptual model of the system.

In the Home Hub of the FitnessVR App (Figure 4.2), a laptop (Instruction Laptop) was located on a table. On this was a set of instructions/hints. A set of users attempted to click on the laptop screen, aiming the laser pointer at the specific instruction that they wanted to follow. While virtually all users found the proper way to interact and pick what activity to do, this still shows that they engaged in a behavior they would likely not in the real world. It seems doubtful that people would start clicking at a laptop screen or pointing at it with a laser pointer in order to make it do something. Again, this shows that somehow, users do not behave in the VR app as they do in the real world, despite certain aspects of the app being designed specifically to behave closely to the real world. One reason for this can simply be that they do not yet know how to perform the action they want, and so start attempting various interaction methods at the first best place they find. They may do this especially because they expect the VR app to allow things that could not happen in the real world. This is also supported by the observation (Figure 4.18) that 11 of the test participants used various means to search for possible interactions in the VR environment such as: pointing at things, clicking, and approaching objects they wanted to interact with. This happened not only with the laptop, but in general across all the scenes of the FitnessVR App.

5.2.3 Observations in relation to gaming experience

Performance in-game

Users with a higher experience with gaming tended to spend less time in-game than low experience gamers. They also tended to register less failed interactions from the games, even though the low experience gamers tended to perform more interactions in total. This can be taken to mean that, if you are more accustomed to the mechanics and tropes of playing video games, you are slightly better at it. This also seems to, at least loosely, imply that the system has been designed in a way that if the user's skill level is higher, then the user performs better. If true, this would be good.

Looking further, the high level gamers spend less time in total in the system. This is bad, since no matter the users' skill level, as much time as possible should be spent in the system to get the benefit of physical exercise. Maybe this tendency comes from the high experience gamers' tendency to more quickly figure out how to play and win the games within the app, or they are more accustomed to similar game experiences, and so move through it more quickly simply because they can or even because they've seen so many better games before that this more primitive implementation did not impress.

However, if we look at the same data, but filter away those users who exercised the least (only a few times per month at max) there is suddenly an increase in total time spent using the FitnessVR App. This increase happens for every group of user irregardless of their gaming experience level. Maybe this means that, even though there are differences between people who have different gaming background, it is actually the users' exercising background that matters more. So people who usually exercise more will also exercise more in the FitnessVR App.

Motivation for different levels of prior gaming experience

The points system, the different exercise games themselves and the VR experience as a whole were the three factors that had the highest number of participants selecting them as motivating factors. This seems to indicate that it is possible to create exercise scenarios in a VR world that are motivating by themselves. By adding a gamified points system to that, it makes the experience further motivating. It was the hope of this master thesis project that these factors would indeed enhance the exercising experience beyond what a traditional exercising session can do. However, it must be noted that those who found the act of doing the exercise games themselves motivating did not necessarily focus so much on the points system, and vice versa. So different groups focus on different things, causing a fragmentation among the factors that helped with motivation. So in this regard it can be considered that the FitnessVR App failed to unify the experience of all its users. On the other hand, such a unification may be impossible, and the right course of action may be to create a wider array of motivating factors, knowing that not everything will motivate everyone, but that everyone will be motivated by something.

As a final remark relating to the participants' gaming experience, it is shown in the results in Figure 4.19 that all the participants with a high gaming experience noticed the Stats Screen, upon which was displayed the current state of the points system. So for users who have experience with gaming, and maybe for users who over time gain such experience, placing important information about user progress in that context likely makes sure that users see it.

Sense of progress for different levels of prior gaming experience

When asked about what made them feel like they had made progress (rather than in-the-moment motivation), *all* the high experience gamers except one stated that the high score/points system gave them that sense of progress. Two of the high experience gamers also stated that the trophies gave them a sense of progress. When looking at the users with low or no gaming experience, none of them felt any sense of progress from the trophies. Five of them felt no sense of progress at all, one of which explicitly stated that this was due to being too distracted by using the FitnessVR App to think about progress. Three such participants also stated that they felt a sense of progress directly from learning the mechanics of the different games. Five low experience users also said that the high score system gave them a sense of progress.

Overall, it seems that the points system, just like with motivation, is the largest factor. This speaks for that gamifying exercises gives the user a sense of progress. Whether this has a good effect over time requires further research, but initial results seem to point toward that gamifying exercises and including a points system helps the users with feeling like they progress.

It appears that if one is familiar with gamified experiences, the high score / points system becomes a default go-to way to measure progress. This behavior is also seen in the low/no game experience users, but they are much more fragmented. A third of them didn't even feel progress at all, stating reasons such as being to distracted by the effort of using the system. So it seems that if you are not that familiar with gamified experiences, it is harder to know what is supposed to be the measurement of your progress. Perhaps it is more difficult to ascertain the purpose itself of what it is that you are doing? But there is also a small number of low/no experience gamers who felt progress simply from learning how to operate the system. This seems to imply that a system with good learnability might enhance the experience of the users positively, contributing to their sense of progress until they familiarize themselves with prevalent gamification concepts and design patterns.

As an additional note on this, *no* high experience gamer missed that there was a scoreboard in the home environment. Among the no/low experience gamers, 7 (so half of them) didn't notice this scoreboard screen at all. A seasoned video game player may know that scoreboards are a common concept found in games, so it is something that they recognize or may even be looking for. Someone who is not familiar with this may lose a whole dimension of the experience just because they didn't think to notice or examine that scoreboard. An in-game introduction highlighting certain features such as the scoreboard may be in order to make sure that no user falls behind on such a central component. The virtual environment could also be constructed in such a way that more attention is drawn to such key areas of the virtual world. But a fine line must be walked between making things blatantly obvious and maintaining the immersion of the environment.

Tennis for different levels of prior game experience

When talking specifically about, a few additional observations can be made. Over half (14) of the users reported no particular sense of purpose at all. 3 explicitly reported that the purpose of the game was unclear. This means that 17 out of 21 participants didn't really.

So there is some kind of a discrepancy between the "high level" and "low level" aspects of the game. While high level gamers consistently factors such as points and scores to be motivating and giving them a sense of overall progress, nearly all (5) of them didn't feel any purpose playing the tennis game. So it appears that when "in the moment", doing something in real-time, it is more difficult to determine how the gamified experience works. But this can also, of course, be because the tennis game was designed to be more open ended with no set event ending it aside from the user deciding they want to do something else. The game can also have been implemented less well than the overall game experience. Additionally, since we have several reports since earlier of users enjoying the the game experience itself, it can simply be that they did not think to report feeling any sense of purpose playing tennis. Perhaps their game-playing experience itself became the purpose, with them consequently not thinking to report their sense of purpose separately. Here is also a flaw in the study, where the post test questionnaire should have more explicitly asked this of the user, rather than relying on open-ended discussion. This introduces more ambiguity into the results.

Time spent in relation to gaming experience

When it comes to exercising, the quantity of exercise matters. If the FitnessVR App is to be of any use, it's likely not enough to fire up the app, play around for a few minutes and then be done.

The results show that those with low, moderate or no prior gaming experience spent *more* time in the system's various exercises. This may be because those who are used to gaming aren't so impressed by the FitnessVR App, since they have more prior experiences to compare it to. And the experience of playing a game may not seem so novel to them.

Another interesting note is that by excluding those who usually only exercised a few times per month, the time spent in the system increased for all categories of prior gaming experience. This seems to indicate that the amount one normally exercises has a bigger impact on how long one uses the system, completely independent from gaming experience. So it is possible that the FitnessVR App is more effective for people who would otherwise exercise anyway.

5.2.4 Comparison between the games

Before comparing results from the different exercises (Figures 4.21 and 4.22), it is important to establish a few differences between them. The Squat Attack exercise was time limited to two minutes, although it could be re-played. Failed repetitions are also defined differently calculated differently across the exercises, so direct comparison is not really possible.

The Dodgeball exercise was implemented last of the exercises and was too difficult to do. It was also poorly implemented from a technical standpoint, making it further impossible to score any successes. So repetitions can't be directly compared with the other exercises. However, it is instead possible look at how participants reacted to a scenario where things do not work, and then compare that to a scenario where things work better.

Considering that most participants spent close to two minutes in the Squat Attack Game Scenario, and two minutes was the time limit for that exercise, it seems that setting a certain time goal keeps the user doing that thing for the entire time period. I conclude that more exercise scenarios would benefit from having timers incorporated. This would not only keep the user doing the exercise, but it would also partly address the complaints issued by some participants that they lacked a sense of what their goal was. Doing something until the timer runs out is in itself a goal and it can maybe become somewhat of a competition to try to do the exercise all the way to the finish line.

5.3 Error Sources

As for what went wrong and what could have been done better, the first thing to come to mind is the broad scope of the FitnessVR App. In hindsight, a much more narrower approach should have been chosen. It became evident that to analyze all the different scenarios from all possible angles created too much bloat. As a result, things such as meditation and mindfulness has not gotten the attention that was initially intended. However, from the point of view of a real commercial product, the current FitnessVR App is still too shallow and lacks functionality. This, I think, goes to show the amount of work that goes into creating a full fledged commercial product. It also shows that to properly analyze every aspect of such a product is not necessarily something that can be contained within one single master thesis, but should rather be done by collecting the results of many related studies.

Some things were also more carefully investigated than others. There was also better data available for some aspects of the analysis. This creates the issues that some of the conclusions may not be a solid as others, because not all conclusions are based on the same quality and quantity of data. With more time or a narrower scope to begin with, a larger percentage of the work done could have been more properly analyzed and included in the discussion.

Some of the data from the participants was also recorded in interviews. The answers open-ended interview questions may have been mis-interpreted. Using more specific question instead of open-ended ones would leave less room for interpretation and it would make sure that the same data is collected from every participant. On the other hand, open-ended answers may give you answers of a higher quality. These qualitative questions may also give answers that you did not know you were looking for, which was what happened here, hence the observation that some relevant questions were not included in the questionnaires but were rather discovered in the analysis.

Chapter 6
Conclusion

The aim of this master thesis was to build a VR app where gamification was combined with exercising.

In conclusion, the work went well and the FitnessVR App shows promise as a basis for what a VR exercising app can be. There was interest from the test participants in the whole premise. The implementation itself was perceived as a solid start.

The gamified elements played a significant role in motivating the participants and giving them a sense of progress. The exercise game scenarios themselves were also motivating. But there should have been a clearer goal for each exercise.

The VR hardware was a little restricting, but not too much, which is promising if even lighter products are released in the future. Interacting with the 3D user interface mostly worked out well, but it was not as intuitive as had been hoped for. Small details and affordances should have been paid more attention to.

People who already exercise more otherwise, spent more time exercising in the app. So the FitnessVR App did not bridge the gap in terms of time exercised between people who usually exercise and people who don't. It remains unclear if this is at all possible, and if so, what factors to focus on.

Chapter 7

Future work

This section discusses potential future avenues of work related to this thesis. What can be done to expand upon the current work or to go more in-depth on a particular subject?

One of the straightforward (but not necessarily easy) ways to increase the success of the FitnessVR App is to spend more time developing more in-game activities and improving the existing ones. A system that is more fun, works better, has less bugs, and presents more variety will very likely see more success in achieving its goals. This project's implementation of the system was largely restricted by time and the game-making experience of the sole, single developer.

As was mentioned in the discussion, the scope of the project was too large. This resulted in some areas being ignored in the discussion either because there wasn't time and space to fit it in or because no there were no interesting findings. For future work, it would be possible to select smaller parts of this thesis and go much further in-depth. Examples could be to study mindfulness in VR or to investigate how good and bad physics and interactions in VR affect immersion and disrupt the user's work flow.

Since the results pointed toward that people who usually exercised spent more time exercising in the FitnessVR App, it would be interesting to see if the app can help people who are forced to exercise. An example could be a person who must rehabilitate due to a medical condition. That person should do exercises every day most likely. So will an app like this help? That could be a potential avenue to explore.

Lastly, the perhaps most intriguing thing about the future is the development of new technology. Things such as eye-tracking, a cordless HMD, reliable and proven VR gloves, and higher display resolution would greatly enhance the experience. This speaks, I think, to the future being brighter for VR in general but also for exercising in VR. It would allow more complex applications and it would put less of a strain on the user.

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Appendices

Appendix A

Test Plan

Test Plan for Fitness and Exercising in Virtual Reality

A Master Thesis by Adrian Hansson

Test

1. **Test session begins.**
2. User is welcomed and receives an introduction to the purpose of the test.
3. User receives a basic introduction to VR.
4. User fills out informed consent form.
5. User fills out a short pre-test questionnaire about general background information
6. User familiarizes themselves with the VR equipment and the play area under the guidance of the test leader (5min).
7. User test commences. Observations are made and noted by the test leader.
8. User fills out SUS survey.
9. User fills out NASA TLX survey.
10. User talks freely about their own observations and experiences.
11. Test leader asks post-test questions
12. Diploma is handed out to the user
13. **Test session ends.**

Introductory Segment

Introductory segment script
Welcome! The purpose of this test is to see if you can exercise when using a Virtual Reality game. Fitness is important to one’s health. And if exercising is boring, maybe you don’t do it at all. What can we do to amend this? Can VR help? Can it help you get the job done and perhaps you’ll even have more fun doing it? We’re going to look at how well you can do physical exercises when inside a VR game. We’re going to be looking at if it’s possible to make a game out of the exercising. And we’re also going to have a look at how well it works to be inside the virtual reality world. The exercises aren’t very physically demanding, so you may not even get tired at all. But to fully test the system, you may have to move around a little, including walking and bending your knees and swinging your arms.

VR introduction
Virtual reality, also called VR, means that you can enter a virtual world. You wear this headset on your head. It is through this that you see and hear the virtual world. In each hand you also hold a hand controller. You can move your hands around while carrying these and your virtual hands inside the VR world will move too. When you want to click something or use something inside the VR world, you can usually just click using this trigger button here. You can move your head to look around. And you can also walk around on this green carpet. When you walk in the real world, you will also walk inside the VR world. Don't worry about hitting any walls. A blue cage will appear inside VR to let you know you shouldn't walk any further. And I will be right next to you and keep an eye on things, like keeping that cord away from your feet and answering any questions you might have.

Scenario Walkthrough
● The goal is to exercise a little (very lightly) and test the game environment. Remember that you can move around, both sideways and up and down. ● Start off by looking around a little, getting a feel for the place. ● Try each exercise at least one time. You can do things in any order, but if you don't know know how to proceed, look around and you might find some clues for what you can do. ● Ask me a question whenever you feel unsure and I will guide you forward.

Pre-test questionnaire

Question	Measurement
Gender	Male, Female, Other
Age	[input age]
How often do you exercise or engage in fitness activities (weight lifting, running, cardio, sports, etc.)?	Never, A few times per month, 1-2 times/week, 3-4 times/week, 5+ times/week
What is your experience level with Virtual Reality (VR)?	No experience at all, Low, Moderate, High
What is your general experience level with computer games?	No experience at all, Low, Moderate, High

Have you tried an earlier version of the “Fitness and Exercising in Virtual Reality” application?	Yes, No

Test Metrics

Metric	**Measurement**	**Measured by**
Time spent exercising	Minutes per game	Recorded by software
Calories burned	Kcal per game	Recorded by software
Exercise repetitions done	Nbr of repetitions per game	Recorded by software
Nbr of failures while exercising	Nbr of failures per game	Recorded by software
Where and how many times does the user get stuck?	Nbr of times	Observed
Where and how many times does the user show strong reactions (good or bad)?	Text + Nbr of times	Observed
Does the user notice background information? (sounds, help texts, prizes, etc)	Text + Yes/No	Observed
Does the user notice or miss any gameplay-relevant functions or interactables?	Text + Yes/No	Observed
Does the user remove their glasses (if they have any) during the test?	Yes/No	Observed

Post-test questionnaire

Question	**Metric**
Did you feel immersed in the game? I.e. did you become engaged, did you forget about the outside world, and did you feel like a part of the virtual world?	Free text
How did the 3D user interface feel? Better or worse than a traditional flat 2D UI? Any advantages/disadvantages to integrate user interactions into the virtual 3D world?	Free text
Did the game help motivate you to continue in any way?	Free text

Did you feel a sense of progress? Did you get anywhere with your training?	Free text
From what you experienced here, do you think it is possible to improve fitness with physical exercising in a virtual reality app?	Free text
Does VR training provide any advantages to ordinary exercising? Or does it present any obstacles?	Free text
Did you feel nausea during any part of the virtual reality experience? Or after it?	Yes/No, When and Where