PURPOSE BUILT EXERGAME DESIGN

PURPOSE BUILT EXERGAME DESIGN

BY
ETHAN CHAN, B.Sc.

A THESIS
SUBMITTED TO THE DEPARTMENT OF COMPUTING & SOFTWARE
AND THE SCHOOL OF GRADUATE STUDIES
OF MCMASTER UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF APPLIED SCIENCE

Master of Applied Science (2022) McMaster University
(Computing & Software) Hamilton, Ontario, Canada

TITLE:	Purpose Built Exergame Design
AUTHOR:	Ethan Chan B.Eng. (Software Engineering & Game Design), McMaster University, Hamilton, Canada
SUPERVISOR:	Jacques Carette
NUMBER OF PAGES:	x, 125

Abstract

Patients with end-stage renal disease that undergo dialysis treatment, visit a hospital on average 3 times a week. Such involved treatment means the patients lead very sedentary lifestyles. The sedentary lifestyle in turn makes the patient less capable and willing to participate in physical activity, worsening the patient's overall health-related quality of life. Video games, more specifically exercise-based games are an existing solution played by many across the world. It offers entertainment and while providing the player a means of exercising. An exercise based game played during treatment may potentially lead to a more active and healthy patient. This thesis explores the design of an exercise-based game for the patients that are required to play, similar to the circumstances the patients that the research project, *Cyclescapes* is being made for. We will learn the design considerations for making the challenges in an exercise based game for an audience that requires it and how to keep the player engaged and moving with respect to their own personal abilities and fitness levels. We then apply the knowledge in the design and creation of Cyclescapes, providing the patients with end-stage renal disease a safe and entertaining player experience that can challenge their physical fitness and improve their health related quality of life.

To my parents, brother and partner,
Y'all are the best, keep on pedalling.

Acknowledgements

Thank you to Dr. Jacques Carette, Dr. Joyce Obeid and Dr. Denise Geiskkovitch who all contributed greatly to the design of Cyclescapes and had a significant impact on the creation on contents of this thesis.

Another thanks to Thien Trandinh, my partner developer in the creation of Cyclescapes, without whom I'd still be writing code and designing the game.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Exercise is a known component for maintaining and improving a person's quality of life and mental well-being[35]. However, not everyone has the luxury of being able to exercise. This may be due to a lack of confidence in one's physical capabilities and/or even a medical condition that limits their ability to be physically active. A group of patient's being cared for at McMaster Children's Hospital fall under the group with a limiting medical condition, that being end-stage renal disease. Currently, the children/patients, ages 3 to 18 years, require treatment visits to the clinic on average three times a week with each visit lasting between three and five hours in order to receive hemodialysis or peritoneal dialysis. The mandatory clinical care interferes with childhood activities such as school and sports. Due to this the children receiving treatment have less time than an average child for active pursuits. As a consequence these youths experience poor physical function [20, 63, 30, 33]. Video games are a well known entertainment medium. Exercise-based video game is a well known option that provides a person a means of being physically active without the monotony of a regular exercise routine. Enter *Cyclescapes*, our attempt at creating an exercise-based game for our patient audience that will entertain the wide patient/player demographic while also providing them an outlet for physical activity. Cyclescapes must cater to the gaming and physical fitness capabilities of a varied audience.

In this thesis we will present our exploration and attempt at designing an exercise-based video game that has the intended purpose of targeting a large audience. In *Fundamentals of Game Design*, Adams mentions the general design guideline to not design a game for everyone due to everyone not enjoying the same thing. Cyclescapes is not a game designed for everyone but does have a large and diverse target demographic. It will be a challenge for the design of Cyclescapes to appeal to all audience members, keeping them entertained and thus give patients a consistent outlet for physical activity.

Note that for our core research problem, the virtual reality video game

domain is not related, it will play a direct role in shaping many of our design decisions with respect to Cyclescapes. The use of virtual reality is mandated by the Health Science researchers we are implementing Cyclescapes for.

1.1 Cyclescapes Summary

1.1.1 Project Description

Cyclescapes is a Virtual Reality(VR) cycling game being developed using the Unity3D game engine. The aim of the game is to provide entertainment and exercise to the player. For the purposes of this thesis and our domain of interest, we will not be discussing the data collection aspect of the system unless it is used in some capacity with respect to implemented gameplay challenges and mechanics of Cyclescapes.

1.1.2 Project Environment

Cyclescapes was developed using the Unity3D game engine. The game will require a VR ready computer, a virtual reality headset, an ANT+ based bike trainer, accompanying bike and a ANT+ compatible heart rate monitor. The game is intended to be played/used in a busy hospital clinic setting.

1.2 Problem Statement and Motivations

Exercise-based video games are a well known alternative to traditional exercise. However exercise as a standalone activity may not be an interesting or engaging for all participants. The lack of interest in exercise may persist even in a gamified activity. For the purposes of the project, if the player loses interest in the exercise-based game and does not play, the desired effect of the game is minimized. Therefore, we want to study *how a game that mandates physical exercise can be adapted to the physical abilities and gaming abilities of the player such that the player is encouraged to move*. This should help us define design practices and consideration for improving future implementations of exercise-based games, including Cyclescapes.

We are exploring and investigating this problem space for the following reasons:

1. To understand the use of game mechanics to motivate player movement in exercise-based games.

2. We want to learn how to design a game challenge based on the mode of movement.

3. We want to learn what aspects of physical fitness should be considered when making a exercise-based game and how they can be connected with game mechanics.

4. To further understanding of the connection between physical exercise in games and exercise-based game, game mechanics.

1.3 Methodology

To investigate the problem statement we have set out to answer we first built a foundation of knowledge with respect to exercise science, game design and exercise game domains. We also included a literature review into the virtual reality space. As mentioned prior, the nature of Cyclescapes required to be a virtual reality game will have a non-trivial impact on the final implementation of the game.

After formalizing our knowledge within the connected domains, we then conducted a review of 4 different exercise games. The games selected were due to their ease of accessibility, popularity or applicability to our problem space. Doing an in-depth analysis of each game will grant us insight to what works in the current marketplace of exercise games. It is important to understand the true intent and extent for certain design decisions may be shrouded by corporate secrets thus any insight we gain needs to be from mass public review or through personal experience with respect to the game.

We then defined the metrics in which we will analyze the 3 core components of our investigation, namely exercise, game challenges and motivation. The defined metrics are intended to be used for analyzing the effectiveness of our design and provide direction for improvements to our implementation. The measurements are a combination of objective measured units as well as an attempt to convert subjective opinion to quantifiable statistics. We note two potential methods for harnessing data for player enjoyment and will use heart rate and power to assess the player's physical attributes. For the purposes of time, we will not be performing live player testing but provide the framework for testing for future work.

For the scope and timing of writing this thesis, we will be designing a user study for the implemented game. However, we will not be running the tests or be conducting any study related analysis. We will assess the effectiveness of our implementation similar to how we conduct our exergame survey in chapter 6.

1.4 Outline and Contributions

This thesis is organized into 11 chapters after this introduction chapter. Chapter 2 introduces the project and problem that is at the centre of this thesis. Chapters 3, 4 and 5 explore the related domain spaces of exercise science, exercise-based games and virtual reality, respectively. Chapter 6 investigates the design of commercially available exercise-based games. Chapter 7 defines the different characteristics we will have available to measure player relevant statistics and our game's effectiveness for the problem we are assigned. Chapter 8 defines the requirements of our game solution as related to the problem statement. Chapter 9 outlines the architecture of our implementation followed by chapter 10 which details the actual designed qualities and features of Cyclescapes. Chapter 11 will outline a proposed user test procedure and considerations. This is required due to current circumstances of the covid 19 pandemic.

The contributions found in this thesis are as follows:

- An overview of exercise science as it relates to the design of exercise-based video games.
- Define exercise-based video games, exergames and defined important characteristics of exergames.
- An overview of gameflow as it relates to the design of exergames.
- An overview of virtual reality game design and its relationship with the exergame domain.
- Expanded on Adams challenge definitions with exergame specific challenges.
- The design and implementation of Cyclescapes, an exergame for a young audience undergoing dialysis treatment.
- The design of a user study to determine the effectiveness of the designed challenges of Cyclescapes.

Chapter 2

Cyclescapes

The introduction chapter provided a brief summary of Cyclescapes and what the project aims to be. This chapter will go into further detail regarding the project scope, stakeholders and their respective goals, the target audience and any project mandates that are required of the final implementation. This chapter will discuss Cyclescapes as a product.

2.1 Project Stakeholders

Each stakeholder in the project has different goals which is obvious but each goal has a non-trivial impact on the final product.

2.1.1 Pediatric Researchers

The pediatric researchers include *Dr. Joyce Obeid* and *Dr. Steven Arora*. Their goal is to determine the effects of 12-weeks of VR-based intradialytic exercise on well-being in children receiving dialysis. The pediatric researchers want address the consequences of chronic hospital visits for children receiving dialysis, which include:

1. Deconditioning, fatigue, and poor functioning
2. Limited time for typical childhood activities
3. Social isolation, reduced optimism
4. Reduced health related quality of life

The design and implementation of Cyclescapes should help the Dr. Obeid and Dr. Arora tackle the above deficits by delivering a physical and emotional stimulus through an engaging exercise-based game format.

2.1.2 Software Engineering Researchers

The software engineering researchers include Ethan Chan, Thien Trandinh and Dr. Jacques Carette. An external third party, Denise Geiskkovitch joined the project later on in the development cycle, providing advice and feedback off the user interface and interaction design. Ethan Chan is the primary author of this thesis, me and part of the development team for Cyclescapes. This thesis will allow us to explore the design of exercise-based games and how to adapt them to a player's physical and gaming abilities. Cyclescapes will provide the opportunity to apply the learned knowledge. Thien Trandinh's goals with Cyclescapes to research game maps and level design in relation to real world maps. He is also part of the Cyclescapes development team.

The work done implementing and developing Cyclescapes is required by Thien and I to obtain a Master's degree of applied science for software engineering.

Dr. Jacques Carette my graduate study supervisor. Through the development of Cyclescapes, he wishes to learn more about virtual reality and software construction of systems similar to Cyclescapes. As the software engineering researchers for Cyclescapes we are responsible for the successful completion the Cyclescapes, defined as a user study ready prototype.

2.1.3 Patients

At the current stage of the Cyclescapes project, the patients or would be players of Cyclescapes do not have any goal or wants of the system. This may change once patients start playing the game and data is collected from them. However Cyclescapes is intended to compete with existing forms of entertainment that the player may already be engaging with during a standard treatment session. Therefore patients/players that will use Cyclescapes will have expectations of the system in the form of entertainment and escapism. To escape their actual realities of being stuck in a hospital rather than doing recreational activities. As the patients using the Cyclescapes system will be primarily children, at least for the initial study, their parents are a related stakeholder group. This group wishes to help improve the fitness capabilities of the patients through the use of Cyclescapes and be able to assess and map the player's fitness to real world situations. An example would be a biking trip from home to school.

2.2 Project Scope

Though the focus of Cyclescapes within the scope of this thesis will be on Cyclescapes as an exercise-based video game/entertainment media, to fully

understand what was designed, this chapter will cover the Data Collection aspect of the software as well. Cyclescapes is a virtual reality exercise game, using pedalling on a bicycle trainer as the mode of exercise. The game will translate real world maps into usable assets for the patients to pedal on.

2.2.1 Purpose

The main purpose of Cyclescapes as an exercise game is to entertain and provide an exercise outlet for the patients who will ultimately be the players of this game. As care giving tool, Cyclescapes is meant to monitor the data that will allow caregivers to assess a patient's performance and improvements. As mentioned before, the project is being done for and in coordination with McMaster's pediatric researchers as a means to assess the viability of virtual reality exercise-based games for sedentary patient populations, namely children who, due to their treatment, lack the time to be physically active. Therefore the system must be able to store player data for future analysis by the research team.

2.2.2 Target Audience

The target audience for Cyclescapes are the patients mentioned at the beginning of 1. The patients cover a large demographic of varied individuals. They range from ages 6 to 18. The children are being treated for end-stage renal disease which requires them to visit the clinic 3 times a week with each visit lasting between 3 to 5 hours in order to receive hemodialysis or peritoneal dialysis. Due the timeline and the global covid-19 pandemic we were unable to conduct in person group interviews with the patients to assess their preferences and experiences with respect to games. We assumed that within the group of patients, there is a wide spread of different experience levels for gaming and virtual reality technology. The target audience being varied in age will also bring vastly different physical fitness levels and expectations.

The words "diverse and ever changing" would neatly sum up the target audience of Cyclescapes. As children, grow not only can their physical abilities be drastically different between sessions but they will also be very different between players.

2.2.3 Project Mandates

The following project mandates covered in this section are derived from the requests of the clients, namely the pediatric healthcare researchers of McMaster University. They are as follows:

- **VR:** The game must be played with the use of a virtual reality system.
- **Bicycle:** The game must use pedalling as its primary method of exercise.
- **Safety:** The game must assume the player does not have access to both arms during play. This assumption comes from two facts. The player balancing on the bike and how McMaster administers dialysis treatment.
- **Mapping:** The game must be able to translate real world data into a usable form in the game.
- **Child-friendly:** To cater to the target audience, the themes used in the game must avoid polarizing themes such as violence and horror.

Chapter 3

Exercise Science

The Cyclescapes project as described in the section 1.1 is an exercise based game. Therefore having an understanding of *Exercise Science* is helpful for making informed design choices.

3.1 Defining Exercise

The terms in the section will help describe what exercise is as well exercise related attributes that help describe the participant.

Physical activity is the basis of exercise. Physical activity refers to any action or movement done with the body through the use of skeletal muscles that increase energy expenditure above rest. The skeletal muscles are the muscles that attach to the skeleton through tendons and create all the movement that can be done by the body as described in [18].

Exercise Any physical activity that is structured, repetitive and done with purpose. Physical exercise can be used to maintain or improve physical fitness.

Physical Fitness refers to the set of attributes/characteristics that a person possesses relating to their ability to perform physical activity. Caspersen *et al.* group components of physical fitness into two distinct types, health related components and skill related components.

For the purposes of Cyclescapes we will be focusing on these health related fitness components; cardioresporatory endurance and muscular endurance.

Cardioreporatory Endurace as defined in [15], is a health related component of physical fitness pertaining to the abiliy of a person to fuel sustained physical activity and remove built up fatigue from the body.

Muscular Endurance as defined in [15] refers to the ability of muscle groups to sustain successive exertions.

The skill related physical fitness component that is of interest in context with Cyclescapes as well as the research problem is power.

Power, as defined in [15], is the skill that relates to the rate at which a person can perform work. Work, the product of force and displacement, can be used as an indicator for effort.

3.2 Exercise Types

The following terms are defined by Patel *et al.* and similar to Laforge *et al.* [35] are used to help standardize the type of exercise we are trying to encourage with our game. To health related fields as well as general knowledge, the following terms can help communicate what experience our system will generate. The terms will allow us to compare other forms of physical activity to our game - such as comparing playing our game to running the 100 meter dash.

Aerobic Exercise is the use of large muscle groups to perform continuous steady-state exertion fuelled by oxygen. Endurance cycling is a form of aerobic exercise.

Anaerobic Exercise is defined as intense physical exercise that is short in duration that is fuelled by the energy sources within the muscle instead of inhaled oxygen. A brief sprint on a bike is a form of anaerobic exercise.

3.3 Exercise Metrics

For the project and our research we require a quantifiable measure that can capture and quantify the amount of exercise a user of the project is achieving. Exercise Intensity will be our method of determining the physiological strain the player experiences during the exercise. The purpose of using exercise intensity for our research is to better define the achievement of exercise from the user. Physical activity intensity is grouped into categories determined by predefined cutoffs depending on the data being assessed. Each category defines a distinct level of exercise. In the domain of exercise science there is no consensus regarding which of many commonly used methods to determine exercise intensity is best [29]. Even with a metric, cutoffs are needed to clearly define each level of intensity. For Cyclescapes and the research problem of this thesis, we only need to monitor the change of exercise intensity from a defined baseline. By monitoring the change the metrics to determine the exercise intensity achieved by a player, we will be able to monitor the success or failure of Cyclescapes to incite physical exertion. We used heart rate, work and speed as indicators for exercise intensity for this project.

3.3.1 Heart Rate

For Cyclescapes and the research environment in conjunction with the project, heart rate is a practical means for measuring exercise intensity. There is a correlation between heart rate and physical activity [32]. To monitor the intensity of the exercise or activity, the participant's current heart rate is compared to their maximum heart rate [29].

The American College of Sports Medicine[48] defines percentage hear rate reserve as follows:

- Very Light: Less than 30%
- Light: 30-39%
- Moderate: 40-59%
- Vigorous: 60-89%
- Near Maximal-Maximal: Greater than or equal to 90%

For use within Cyclescapes it satisfies our needs by knowing that a change in heart rate implies a change in physical exercise intensity for the end user.

3.3.2 Work Rate and Speed

Maximal work rate and maximal speed are potential methods of assessing or prescribing physical activity intensity. By assessing at what percentage of their maximum work or velocity the relative intensity of the activity can be monitored. However, to my knowledge their is no agreed upon cutoff for categorizing different percentages of maximum work or velocity as distinct levels of intensity such as low, moderate or heavy. Like heart rate however, it is adequate to know that intensity was increased or decreased for the end user.

3.3.3 Relative Accuracy

Heart rate maximum and work/speed maximum comparisons are both easily accessible for the project due to the accessibility of the technology and ease of integration with the Unity3D game engine as mentioned in Section 1.1. For the purposes of the project and for answering our research question, we are not concerned with exact levels of physical intensity experienced during a given activity but rather that physical activity is being achieved. For these reasons heart rate monitoring, work and speed monitoring will provide the system data to quantifying the physical activity level of the player, in very relative terms.

Chapter 4

Exergames

Oh and Yang's survey of literature regarding the definition of an exergame concluded that the word exergame has different meanings depending on the context and people that use it [43]. In the health-related research space, exergames must increase the level of physical activity of a player. In the health research and exercise science domain, exergames are sometimes called activity promoting video games or active video games. For the purposes of clarity, in this thesis we will now use the term exergame to reference the following definition, derived from the definition found in [43].

Definition 4 An **exergame** is any video game that requires physical exertion or movement that is more intense than sedentary activities such as playing a video game on a personal computer.

4.1 Exergame Design

The player experience presented in an exergame, like that of traditional video games, can be vastly different even if the exergames have the unifying characteristic of the requiring the player to move. An exergame label for a video game defines only the type of input used by the game but the how the player input is used has a non-trivial impact on the player experience. Understanding how movement input can be used in a video game context and how more traditional approaches to game design relate to exergames can allow us as game designers and developers to create the most fitting player experience we want for the game's purpose. From there we can begin to learn what aspects of an exergame's design can be altered to adapt to the player.

4.1.1 Games with Exercise vs Physically Active Games

Through all the literature we came across there was not a clearly defined difference between a game with exercise and a physically active game. Both meet the qualification of an exergame, as defined above but we believe it is important to make a distinction here. For the purposes Cyclescapes and the problem we wish to address, the distinction between the two should be clear as it can strongly influence the design decisions made for the project. We will define the focus of each approach to designing an exergame as the drive of the game. During our research, we did not find a clearly defined difference between a game with exercise versus exercise driven game. We define them as follows:

Definition 4.1.1 An **Exercise Driven** exergame is when a game uses gamification and game mechanics to get the player to move in *specific* ways. In our review of the games listed in chapter 6, *Hot Squat* is one such exercise driven exergame.

Definition 4.1.2 A **Game Driven** exergame is when an exergame elicits movement of the player through use of its game mechanics but does not care how the exertion and exercise is achieved.

When comparing a game that is exercise driven exergame and a game driven exergamee, we found that the crucial difference is in the use of an **exercise protocol**. As a real life analog we can compare a sport such as basketball against going to the gym. Like both versions of exergame, both basketball and going to the gym for a workout end up with the participant performing some form of physical exertion. However, when the participant is at the gym there is a set routine that they perform. As for the game of basketball, the participant is focused on scoring the most points and physical movement and exertion is the mechanism that allows them to accomplish this goal. For the purposes of this thesis we will define exercise protocol as:

Definition 4.1.3 An **Exercise Protocol** is a routine performed during exercise designed to improve or maintain a person's physical fitness.

The use of an exercise protocol in an exergame does not inherently reduce fun and entertainment value. Rather, it gives context as to why the exercise/exertion is being performed by the player. An example exercise protocol is high intensity interval training. It is present in a game known as Zombies, Run [10] and involves specific intervals of high intensity movement such as

sprinting paired with low intensity movement with the participant alternating between the two modes of movement throughout the planned workout routine.

4.1.2 Flow and Exergames

In researching motivation and design considerations for exergames and general game design, the idea of applying flow theory and its game design variant aptly named gameflow was a reoccurring idea [51, 27, 55]. Sinclair *et al.* describe the state of flow with respect to sports and physical exercise as being equivalent to being in the zone. Both flow and gameflow refer to a state of being where the participant of the activity experiences very specific characteristics as summarized in the paper *Flow Theory and Research* by Nakamura and Csikszentmihalyi:

- Extreme focus and concentration on the present moment.
- Merging of action and awareness.
- Loss of self consciousness.
- A sense of control over one's actions.
- Distortion in the experience of the passage of time.
- The experience of the activity is rewarding to the participant.

To achieve the flow experience in a generic sense, the activity should have the following elements as summarized by [40, 58] and more thoroughly explained in *Flow: The psychology of optimal experience* [17].

1. The task can be completed.
2. The participant can concentrate on the task.
3. The task has clear goals.
4. The task provides immediate feedback.
5. The participant has a sense of control over their actions.
6. The engagement with the task removes the participant's awareness of everyday life.
7. The concern for self disappears.
8. The participant's sense of the passage of time is altered.

Game Terminology	Flow
The Game	A Task that can be completed
Concentration	The ability to concentrate on the task
Challenge Player Skills	Perceived skills should match challenges and both must exceed a certain threshold
Control	An ability to exercise a sense of control over actions
Clear Goals	The task has clear goals
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement, reduced concern for self and sense of time

Table 4.1: The mapping of flow theory to game literature taken from GameFlow: Model for Evaluation Player Enjoyment in Games. [58]

The intention behind understanding flow and applying the concept to the project, to Cyclescapes is to create a strong sense of enjoyment and reward for the player. For the purposes of the project, if we are able to instill a sense of the flow experience in the player we will have checked off the project goals of entertaining the player/patient and providing them an outlet to escape their present reality.

To apply the concept of flow theory to games, the game variant gameflow a model for applying flow to video games specifically was discussed in *GameFlow: A Model for Evaluating Player Enjoyment in Games* written by Sweetser and Wyeth. In table 4.1, mapped by Sweetser and Wyeth, it shows the mapping of the above concepts of flow theory into game terminology.

In the original mapping between gameflow and flow by Nakamura and Csikszentmihalyi, there is a ninth element described in gameflow not found in flow labelled *Social Interaction*. Due to time constraints as well as the *Covid 19* global pandemic, we will not be covering or integrating social interactions into Cyclescapes. However, we acknowledge that exploration of how social interactions is a significant to motivational factors when it comes to gameplay, this will be left to future work.

4.2 Dual Flow

Sinclair *et al.* propose design considerations for making better exergames to combat rising obesity. In their paper *Considerations for the design of exergames*, [55], they discuss two major components to making an exergames, the exercise and the game. By giving users a means of enjoying exercise the hope is that the users will continue exercising. Similar to our purposes for

creating Cyclescapes we seek to create an exergame that can motivate the patients to exert and stick with the exercise. An exergame must be attractive and effective. The attractiveness as described by Sinclair *et al.* encapsulates the enjoyment and entertainment value provided by a given system. In other words the fun experienced by the player when playing the game.

The effectiveness of an exergame refers to the health benefits through exercise of the system. While gameflow models the balance between game challenge and player skill, Sinclair *et al.* extends the model by adding a physiological dimension, adapting gameflow to exercise. Sinclair, Hingston and Masek's *Dual Flow* model visualized in figure 4.1, focuses on the balance between player fitness levels and the intensity of a given task. As depicted in figure 4.1, for attractiveness ("fun") it is a balance between player skill and the challenge presented through the game's gameplay. For balancing effectiveness it is requires the optimization of game intensity with respect to physical exertion and the player's physical fitness.

Though it can be misinterpreted through the model in figure 4.1 that challenge and intensity are discrete parts of a whole, in exergames it is important to consider the potential influence a game challenge can have on the physical intensity of the exergame. Depending on what mechanics are chosen with respect to the design of the exergame, how the game is balanced when using dual flow as a guide changes. An exergame where the physical exertion required of a given gameplay challenge is high will garner a different experience compared to an exergame where the challenge is not as demanding on physical fitness and is more game like.

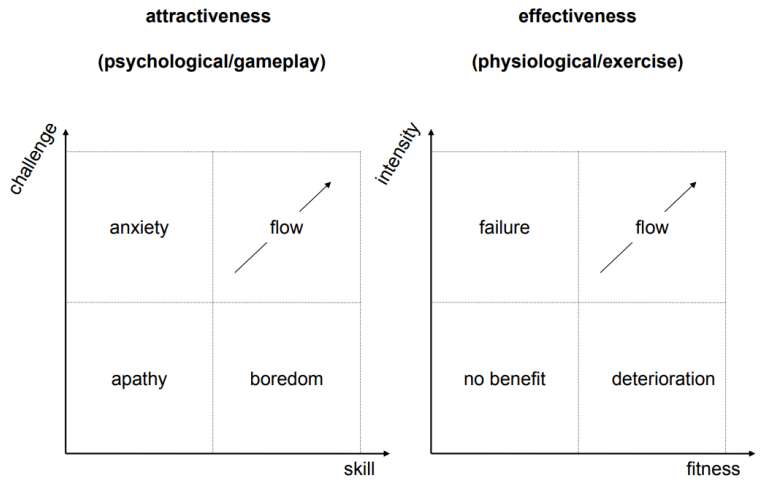


Figure 4.1: Dual flow model as presented by Sinclair *et al.*

4.3 Achieving Flow

The guideline for achieving our project objectives as well as exploring our problem is distilled into four main points as described by Schell, and used in the paper *Minebike: Exergaming with minecraft*, Huh *et al.*.

- Clear Goals
- Minimum Distractions
- Clear Feedback
- Continuous Challenge

4.3.1 Clear Goals

The goal for the player must be easily understood. The reason is that having a clear goal allows for the end user, our player to stay more focused on the task, thus facilitating the game flow state of mind [51]. The system must also communicate the goals to the player clearly.

4.3.2 Minimum Distractions

A minor inclusion to this background study is Cognitive Load Theory. Cognitive Load Theory is based on many cognitive theories of human architecture and the major assumption that human working memory is limited by a certain capacity [13]. Though Cognitive Load Theory has its origins in the study of learning the assumption made is one that is applicable for our purposes as well. Therefore for the design of our project, Cyclescapes as well as this thesis we will assume the same. The player has a limited cognitive load capacity. As such, distractions within the system must be kept to a minimum to further enhance the concentration of a player on the core tasks/challenges. Distractions can come in the form of a poorly designed environment or overloading the player with too many tasks to complete. By maximizing a player's concentration it should enhance their enjoyment during the experience and hopefully help them transition into a flow state.

4.3.3 Clear Feedback

To keep the player's attention on the game and the ongoing events generated by the system, the player must have immediate feedback with regards to the changes of state. Feedback can come in many forms and has potential to help the player with regards to goal setting when playing the game. This then allows the player to dedicate more concentration on the challenge presented by the game.

4.3.4 Continuous Challenge

We have mentioned the term challenge quite frequently in this thesis thus far as it is an integral aspect of what we are exploring within this problem space. We define challenge as follows.

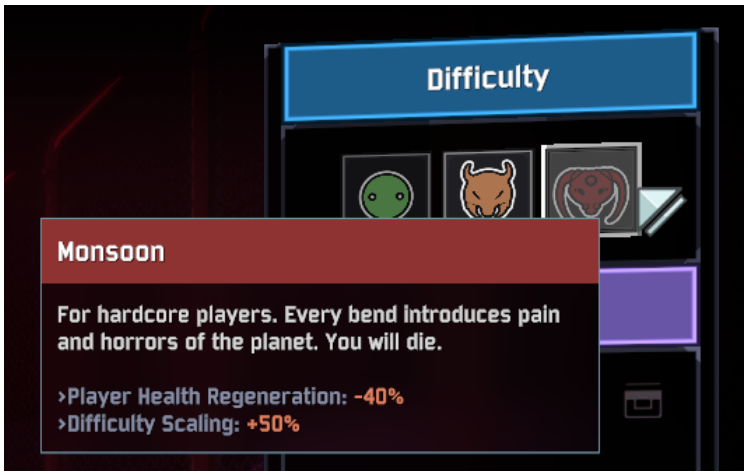
Definition 4.3 A **Challenge** is any in-game activity with a success condition which engages the player in some level of either physical or cognitive proficiency [56].

With respect to the dual flow model, as well as the knowledge gained from studying flow state, a challenge presented must give the player a sense that they can complete the challenge. Following the dual flow model, the game challenges must be difficult enough such that the player skill is adequately tested but also balance the exertion required of the challenge against the fitness of the player. The exertion required of a given game challenge should be achievable given the player's fitness capabilities. During our investigation into continuous challenge, the term Difficulty Adjustment was frequently encountered as well as Dynamic Difficulty Adjustment. Both refer to adjusting the difficulty of a video game. Dynamic Difficulty Adjustment refer to techniques that automatically adjust game play challenge based on set parameters. There are many techniques with respect to altering the difficulty/challenge of a game and they are not mutually exclusive. An example game that allows the player to manually set a difficulty as well as dynamically adjust its own difficulty is *Risk of Rain 2*[23], Drummond [19]. Figure 4.2 shows both manually selecting a difficulty in *Risk of Rain 2* and the difficulty scaling found in game relative to time played in a given session.

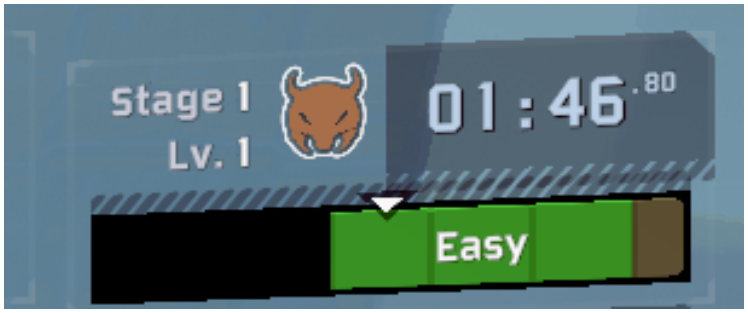
4.4 Exergame Design Summary

An exergame is about balancing exercise against a game's mechanics and challenges. As designer or developer the use of an exercise protocol will make the exercise more apparent to the player making exergame a game with exercise. A physically active game shapes the player's movement through the implemented challenges for the player rather than a preset routine.

The balancing act between game challenges and exercise also applies to players. The flow model in game design is discussed to keep a player focused and engaged with a game. In sports and exercise it also known as *"Being in the zone"*. The dual flow model shows the aspects that must be balanced within the player experience of an exergame. An exergame's challenge must be matched to the player's skill. The exergame's physical intensity must match a player's physical fitness. The player should always be informed of their task,



(a) Difficulty select at session setup for Risk of Rain 2.



(b) Dynamic Difficulty relative to time parameter during a session of Risk of Rain 2

Figure 4.2: Manual Difficulty selection versus Dynamic Difficulty Scaling in Risk of Rain 2.

be allowed to focus on the task and be informed of how well they are doing in regards to their task. The challenge of completing their task should be balanced to challenge the player's skill and fitness as seen in figure 4.1.

4.4.1 Cyclescapes, Exergames and Safety

As the designers, developers and researchers working with the youth patient population that will be the player, their safety must come first. For this reason it is important that exergames designed for such a population take into considerations the potential negative effects of overexertion. The exergame should take into consideration what a comfortable level of exercise is, striking a balance between the difficulty of the exercise, effort required to complete the activity, the fun and attractiveness of the challenge and the safety of the player. All exergames should not make the player do something that is dangerous.

Chapter 5

Virtual Reality

Virtual Reality(VR) is a required component of Cyclescapes. Though virtual reality is not directly related to our research problem space it will have a non-trivial impact on the design choices made for Cyclescapes. The intent behind using VR with Cyclescapes is to allow the McMaster Children's Hospital researchers to evaluate the effectiveness of VR to immerse the player during their treatment and hopefully providing a stronger sense of escapism from their normal hospital setting and ultimately enjoyment/entertainment during treatment.

5.1 Virtual Reality 101

As defined by Zheng *et al.*, VR is an advanced human computer interaction that involves creating a realistic environment. Defined by Pallavicini *et al.*, VR lets users interact in real-time with a 3 dimensional computer generated environment. Whether it be for style reasons or for optimization, many commercial VR video games play in very stylized generated environments, see figure 5.3 as an example. Therefore a VR game does not require a realistic looking environment. For our purposes, the virtual environment need not be realistic but it only needs to be generated environment that can be interacted with.

The power of VR systems comes from its ability to take up significant bandwidth for a person's sense of sight and hearing while also mapping bodily movement to in system movement. This mapping allows the player to use their sense of proprioception, the sense that allows a person to know the location and actions of the parts of the body [60]. With VR becoming more affordable and accessible with devices like the *Oculus Quest 2*, VR can potentially serve as a means to extend exergaming into a new space of entertainment.

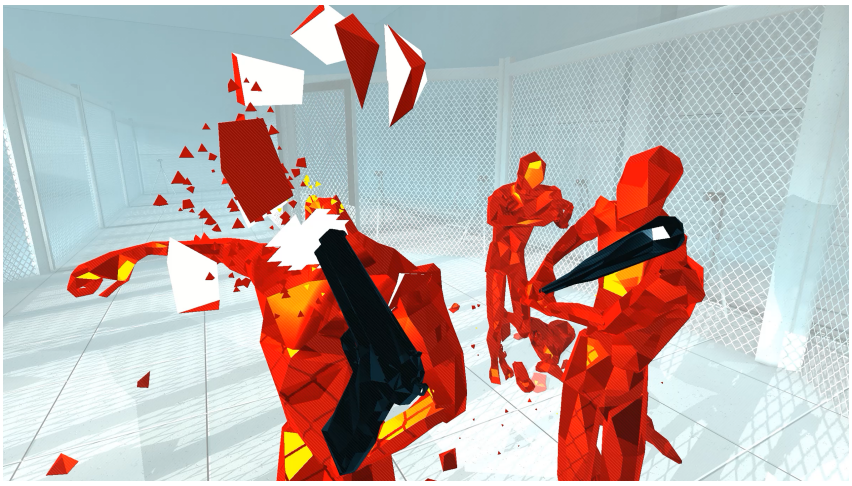


Figure 5.3: Screen shot of Super Hot VR[57], a VR game. [42].

5.1.1 VR versus Traditional Video Games

When discussing the design of Cyclescapes and understanding the rationale behind choosing to build a VR game we must understand what we can do in a VR game. Then we can compare it to a traditional game and see what benefits it grants us. VR games are described as immersive experiences, where the player has their senses transported to a virtual environment. Based on a study published in 2017 by Shelstad *et al.* with the *Oculus Rift*, satisfaction based on engrossment, enjoyment and creative freedom were higher than response satisfaction scores from traditional monitor play. However, satisfaction scores from this study only conducted surveys with a tower defence game and there might be a factor that needs to be considered with respect to game genre and medium. The effect of VR games being more enjoyable was also supported by [44]. They found that user enjoyment was more enjoyable in a VR game versus a tablet counterpart. In a study done by Porter III *et al.*, comparing VR minecraft to the screen based version, it was found that players preferred playing minecraft in VR due to the increased immersion into the game world. Admittedly, within this domain, more rigorous tests can be conducted to determine the longevity of the benefits provided. Is the enjoyment with VR coming from the novelty of the technology? Are there experiences that won't map well as a VR game? For the purposes of Cyclescapes, we will hypothesize based on the literature read that the satisfaction bonus provided by VR is not temporary given that the experience is being tailored for VR. This logic stems from personal experience within the VR gaming space as well as the studies we have explored. Future research with our collaborators will explore the entertainment longevity of Cyclescapes.

Figure 5.4: Gorn gameplay. [50].

Room scale is a technique that can be employed by VR systems that is unavailable to traditional screen based video games. Through the use of tracking player positioning in a 3D space, the system models the majority of the players movement and positioning into the virtual space. This allows real world movement to map directly to in-game movement, [52]. For games such as Gorn [50], room scale has been shown to contribute to the fitness potential of a VR game. Gorn won the VR Fitness Award for best VR Fighting Fitness Game of the Year in 2017, [50]. Figure 5.4 is a screenshot of Gorn game play demonstrating the movement used to swing the weapons as best an image can show. Due to the safety requirements provided by the Cyclescapes project a bicycle trainer will instead be our main mode of movement input. Room scale as a technique is less relevant to Cyclescapes due the player being seated.

Cyclescapes will a seated VR experience. This limits the degrees of freedom a player has to move but will match the safety and hardware constraints of the project. We can learn from games like Gorn for game design patterns and how to incite exercise in the player. It will be interesting to see if a seated VR experience can match a Room scale VR experience with the aid of additional hardware.

5.1.2 Problems with VR

Even with all its benefits, VR does come with some issues. Tran, in their study discuss three concerns that come with the prolonged use of VR systems - more specifically systems that use a head mounted display. They are simulator sickness, ergonomic stress, and visual fatigue.

Simulator Sickness is where the user feels symptoms similar to motion sickness during or after experiencing a simulated environment such as VR,

[34]. Kolasinski, in their research also cover the 3 main categories of potential factors that contribute to simulator sickness. There are factors of the individual, factors of the simulator and factors of the task. With regards to the individual, these are factors we cannot change, such as the person's natural ability to tolerate the VR experience. Factors related to the simulator deals with the actual hardware being used, thus this can be altered or taken into account by selecting the best VR head mounted display. What can be designed to minimize simulator sickness when using our system is the actual tasks in the game. Some aspects to consider when design a VR game would be the movement type, one example being teleportation and physical movement driven in game movement. For the teleportation method the player points relative to the virtual space in a direction that they want to go and then clicking a button to cause an instant position shift. Physical movement driven movement refers to movement that uses some form of real life movement of the player - such as swinging of the arms to control movement speed and sometimes direction as well. An example game that does this well is *Gorilla Tag*, a free VR game, [12].

Then there is also the issue of added weight from the head mounted display.Though potentially insignificant for a shorter play session with the VR system, prolonged use may cause discomfort and strain on the players neck. From our own experiences with VR and more specifically the VR system the *HTC Vive*, prolonged use of a VR headset has the potential to lead to muscle fatigue in the neck depending on the posture adopted by the player during play. Though the issue of neck strain and ergonomics may seem minor for short duration sessions, it should still be taken into consideration when designing the VR portions of the game due to the wide demographic of players making it more difficult for us as designers to predict reactions to the use of our system.

The study of balancing enjoyment, movement and exertion in VR games, conducted by Yoo *et al.* touched on the problem of sweating while in VR. Due to the VR system being a sealed mask the potential build up of sweat within the lens area of the head mounted display will also be an issue that limits playtime in VR. The heat generated from the body as well as the sweat has the consequence of fogging up the lens of the head mounted display, reducing enjoyment during play. This issue is guaranteed to come up during the playing and use of Cyclescapes due to the nature of being explicitly designed as an exergame, and will be explored in future user testing.

5.2 Hardware

The commercial availability of VR systems is only increasing with high end devices such as the *Valve Index* and more portable and affordable options,

such as the *Oculus Quest 2*. Most commercial VR systems act as peripheral devices that are installed and connected to a computer that has the graphical processing power for VR environments. All head mounted displays come with two screens that are viewed by the player through two individual lenses and a method for tracking the position and orientation of the head mounted display. Finally some VR systems do come with hand held remotes that allow for the tracking of the player's hands and additional inputs for the player to interact with the virtual environment.

For our purposes, we will be developing for the *HTC Vive Cosmos* [6]. We are using the Vive Cosmos mainly due to it being quick to set up. The Vive Cosmos uses an inside out tracking technology that uses the onboard cameras and sensors to determine headset movement and orientation. By tracking player movement in this way, there will be no need to set up external tracking devices such as the *Valve Index*'s lighthouses. The decision to use the Vive Cosmos were based on the requirement for the VR system to be portable, moving from one clinic room to another. We will still have access to OpenXR for developing making it easier to port to another OpenXR supported headset if the decision to change VR system occurs.

Figure 5.5: A picture of the *HTC Vive Cosmos* taken from a review written in PCMag, [25].

5.3 Virtual Reality Exergaming

Many VR experiences are exergames by the definition we have outlined. Though it may not have been the original intent of the creators, games like *Beat Saber*, *Fruit Ninja VR* and many other VR games have movement intertwined with the core to its game mechanics that as a consequence cause the player to move

and exert as if they were doing physical exercise. The quantity of exertion may vary between different VR titles. VR is a technology capable of fully immersing a player within the virtual environment of their choice. The selected virtual environment can encourage players to work harder during bouts of physical exertion, [66]. This is corroborated in this 2017 pilot study, [67]. They compared cycling done on a stationary bike against cycling using the VR system VirZoom which uses a custom exercise in conjunction with a VR head mounted display. In this study they selected two minigames provided by the system based on the observed level of physical activity intensity to being the highest. They found that exercising on the VR system was an effective tool in encouraging and motivating physical activity. Between the standalone stationary bike and the VR enhanced cycling, participants enjoyed the VR cycling more and had significantly higher self-efficacy.

5.4 Virtual Reality Design Considerations

Though we now know that VR is a potential boon to exergaming, we must understand or outline what makes a VR exergaming experience more appealing. A study done by Farič *et al.* analyzed reviews of VR exergames. The most interesting takeaways from the survey relevant to Cyclescapes were:

- Actions mimicking real life activities are more appealing.
- Intuitive controls minimized frustrations and improved immersion.
- Immersion distracted from the actual physical exertion being performed.
- Music made for a better experience.
- Motion Sickness (Simulator Sickness) made player engagement difficult.
- Players enjoyed gradual increases in difficulty.

As noted in their discussion on the limitations of their study, Farič *et al.* mentions the possible bias in the data analyzed due to the nature of its source and the lack of control over the test environment used when players played the games.

Yoo *et al.* created the VRmove framework for the design of VR exergames by analyzing 4 different VR exergames. For our purposes we will be analyzing it and use it as a starting point for our own design approach with respect to creating an exergame using VR. Figure 5.6 shows a summary of the findings connecting the VRmove framework with enjoyment factors discussed in the paper.

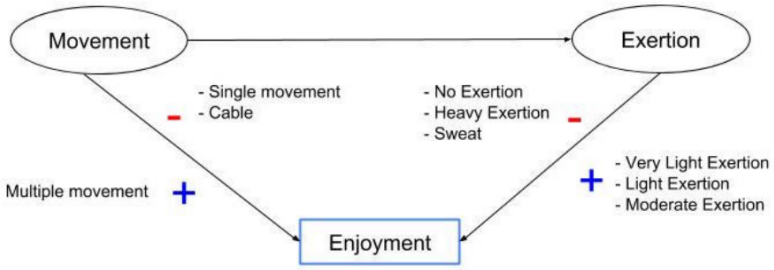


Figure 5.6: VRmove framework with respect to enjoyment factors. + represent positive contribution to enjoyment. - represent negative contribution to enjoyment. [66]

The VRmove framework focuses on 3 aspects of Vr Exergaming, they are movement, perceived exertion and actual exertion. A VR exergame should aim to have many different kinds of movement. They also found that very light to moderate amounts of exertion would be optimal for enjoyment. Playing within a VR system brings along with it health and safety concerns relative to the user/player. For Cyclescapes and due to the multiple user requirement, hygiene is an important consideration. As mentioned by [53], sweat can be absorbed by the spongy pads of the head mounted display making the headset unhygienic to share. From a hardware perspective - designing a protocol for handling and cleaning VR hardware. This approach falls outside our scope of interest for this thesis. The software/game design approach would be to consider the amount of physical activity that is achieved through the mechanics of the game. With respect to health and hygiene for VR we should consider factors such as session duration and range of physical activity intensity.

Chapter 6

Exergame Survey

To further understand what makes an exergame successful, we will perform an analysis on existing exergame in the consumer space. Each game selected is based on personal experience, ease of access and popularity. Selecting titles based on personal experience allows for a more engaged analysis of the game as it made it possible to play test the game. We determine popularity based on how prevalent the exergame is in popular culture. Popularity is a required characteristic of a game as it is more convenient to collect reviews and data that reflect the consumer sentiment in regards to the chosen game title. Games that are popular will tell us what features perform well - following a similar theme to the [21] study.

The exergames being analyzed are *Zombies, Run!*, *Pokemon GO*, *Ring Fit Adventure* and *Hot Squat*. The games selected are not all implemented with the use of VR technology. *Zombies, Run!* and *Pokemon GO* are mobile augmented reality experiences. *Ring Fit Adventure* is a console game played with the use of the *Nintendo Switch*'s specialized controllers. *Hot Squat* is the only VR game that will be analyzed.

We understand that in the indoor cycling training domain there are products that serve the purpose of enabling cyclist to train indoors. The most popular would be *Zwift*[69]. Zwift is a very well-built and fully featured system that understands who their target audience are. The modes available are directed towards adult audience, primarily focused on training rather than gaming. The primary means of engaging its users is through social competition in the form of races. Additionally, the pricing model for Zwift is a subscription based making a thorough investigation of the system a bit more costly. For these reasons we will not be assessing Zwift more deeply with respect to this thesis and our purpose.

Each section of this chapter will go into further detail with regards to our thoughts and findings for each game title respectively. The last section of this chapter will be a summary for all games in table format inspired by the

analysis done in [66].

6.1 Analysis Focus

To analyze each game we need to approach it from the lens of our research question. To reiterate, we wish to answer *"How can a game that mandates physical exercise be adapted to the physical and gaming abilities of the player such that the player is encouraged to move"*. We will analyze the games with respect to the following aspects:

- Physical Activity
- Game Mechanics
- Method of Motivating the player
- Adaptability

To analyze **physical activity** we will be looking at what physical movement is used in the game, how it is used and the approximate level of exertion as observed by analogous physical activity. We will also look at how the game balances the difficulty of the physical activity against the player's physical fitness capabilities. To analyze the **game mechanics** we will be looking at what interactions are possible for the player when playing the game. What are the challenges and goals that make up the player experience for a specific game. For the purposes of this thesis we will be focusing on the game mechanics that tie into the physical aspects of a game while taking note of whether or not a game has a significant number of mechanics not tied to the physical exercise encouraged by the system. For analyzing the **method of motivating the player** we will look at the design choices in the game as a whole and attempt to discern how they intend to get the players moving, how the game engages the player and encourages physical movement. The last aspect of the games we wish to analyze is the **adaptability** of a game. How does a game adapt to its audience. Does the game allow the player to make changes with respect to the exercise and the game's mechanics. The intent of analyzing adaptability to assess and learn how a game changes itself to fit the player. By performing an analysis on these aspects, we may be able to gain insight that will further guide our design choices while still employing the lessons learned from our literature review into the exergaming and game design space.

We will first analyze both mobile augmented reality games, *Zombies, Run* and *Pokemon GO* to take a look at design choices present in two games that use the same technology and analyze the 2 distinct player experiences. Then we will look at *Ring Fit Adventure* for its myriad of exercise implementations

and exercise focused gameplay. Finally we will analyze *Hot Squat*, an exergame that uses VR technology but is also extremely restricted, by choice in terms of required play space to play the game - a characteristic similar to our circumstances with Cyclescapes.

6.2 Zombies, Run

Zombies, Run[61] as described by one of its creators is an ultra-immersive running game and audio adventure [10]. We selected *Zombies, Run* this title due to its popularity on the Apple's App Store and Google's Play Store and the enforcement of cardiovascular exercise as its only form of exercise within the game.

6.2.1 Physical Activity

The game focuses predominantly of long form aerobic exercise. The player/user of app is to run during the duration of their session. The game itself provides multiple ways to track player movement. Figure 6.5 shows the available methods for the app to track player movement. The advertised use is tracking the player through GPS as mentioned before. However, to make the app more accessible there are options for tracking indoor running as well as alternatives to running. The game also offers workout similar to that of high intensity interval training. This provides a higher intensity workout for those players who seek it.

Figure 6.5: Tracking options available within the game, Zombies, Run. Screenshots taken on a mobile device.

6.2.2 Game Mechanics

The games sessions are split into missions. The core mechanic of the game is letting the player listen to audio that connects to the physical activity. There is the main story missions that ties into the base building mechanic. The narrative of the core game is focused around the player as a runner who goes into a zombie filled world collecting materials and unravelling a thrilling narrative. When running through a story mission, the player collects materials by simply running. Figure 6.6 shows the mission select screen within the app. The main campaign are the Story Missions as seen in 6.6 grouped into different seasons.

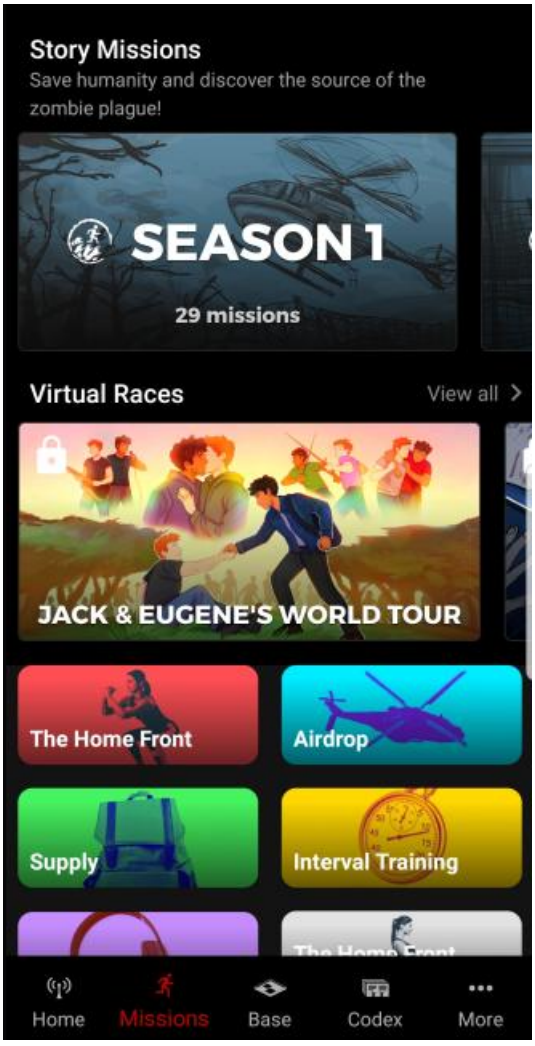


Figure 6.6: The main mission select screen in Zombies, Run.

With the materials collected they can then expand their base making it bigger and better. The player can track their base's population of survivors,

level of defence against zombies and survivor morale. To our knowledge the base building mechanic serves as a method for tracking and rewarding player achievement in the core story missions. Figure 6.7 is a screenshot taken from within the app showing the base building interface.

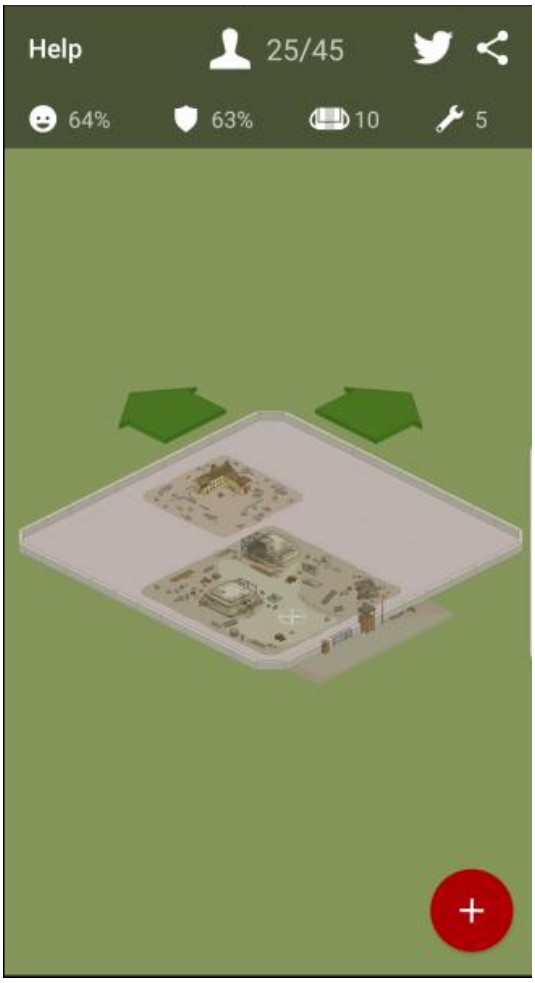


Figure 6.7: The base building screen within Zombies, Run.

As mentioned before, there is a chase option when setting up a mission. For the core story missions this involves running away from the zombies at a higher speed. The player must maintain the increased speed for 1 minute. If the player is unable to maintain the increased speed they are caught. Chases are an optional mechanic even during a run. A player being caught does not cause them to fail their current mission. Instead the player loses supply - a currency used towards base building. This support article published by the developers thoroughly describes the workings of the chase mechanic, `https://support.sixtostart.com/hc/en-us/articles/203780596-How-do-Zombie-Chases-work-I-keep-getti` [4].

6.2.3 Motivation

Zombies, Run makes a strong use of "Pretending" to encourage the player to participate in the required physical activity. By placing the player in an immersive narrative experience the player is given goals that are part of the narrative that continue to expand as the player continues their physical exercise. By giving players goals outside of just exercising it gives players more reasons to run. The use of the chase mechanic also incentives increased exertion but does not punish the player to severely if they fail to keep up. Overall the does a great job using story-based goal setting to encourage the player to run.

6.2.4 Adaptability

Even with the very specific genre title, *Zombies, Run* offers a lot of variety when it comes to the narrative aspects of the game. If the theme of zombies does not intrigue the player there are whole other stories as seen in figure 6.8. Each provide its own unique running related narrative. The game also offers an alternative running style termed race missions. Different from the core missions, race missions are distance based rather than duration based. *Zombies, Run* having a suite of stories as well as alternate play modes allows for greater customization of the player experience with respect to the game side of the exergame.

As for the physical exercise within the game, *Zombies, Run* allows the player to adjust duration or distance of a session. The actual difficulty of exercise determined by the pace of the player as well as distance or duration of the session. For the chase mechanic of the game, the player is able to adjust the frequency at which they occur. Unfortunately this feature is kept behind a paywall making is more difficult to access.

6.2.5 Zombies, Run Analysis Conclusion

Zombies, Run is an example of an exergame that is accessible and entertaining. It has a positive track record on Apple App Store with a score of 4.8/5 and over a million downloads with a 4.4 star rating on the Google Play Store. Through the use of narrative and mapping real world activity to in game goals *Zombies, Run* is able to fully engage players into their cardio exercise. The use of engaging audio, we suspect distracts the player from the actual exertion involved as we have personally experienced. The audio produced an effect in our running similar to running while listening to music. This effect similar to the exergame review study consideration of music [21]. This exergame demonstrates that story can also be a strong motivator for physical activity if it is directly related to the physical activity. In our experience playing

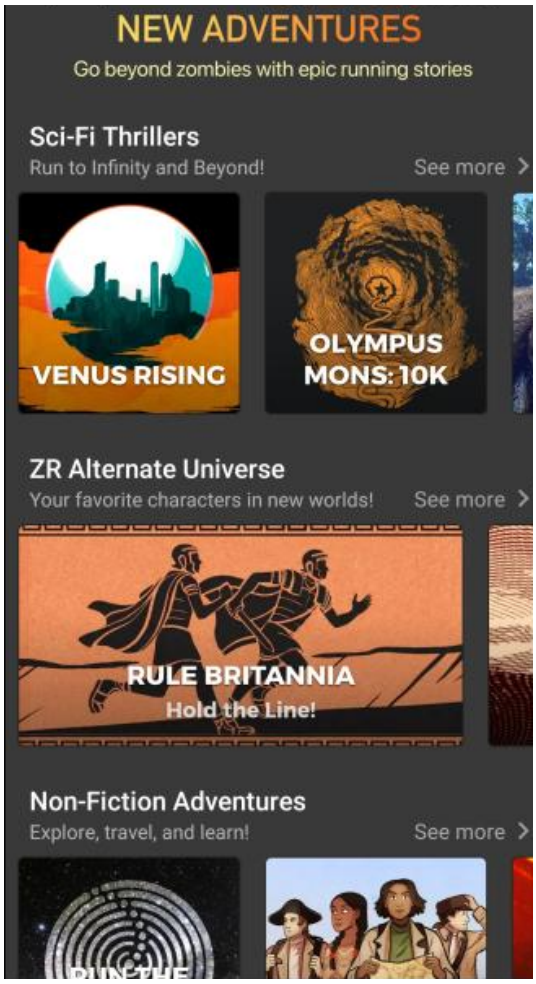


Figure 6.8: Sample of alternative stories within Zombies, Run.

Zombies, Run is similar to watching a movie while on a treadmill or listening to a podcast while doing a very repetitive action. A potential concern with the methodology chosen with respect to its design is the limit to content. Relying on a narrative to engage the player can potentially cause the audio to become repetitive, similar to watching the same group of movies over and over again. The original novelty of the story fades with time, thus *Zombies, Run* requires a reliable stream of new adventures and stories to drive its longevity as a popular exergaming application.

6.3 Pokemon Go

Pokemon Go[41] is an augmented reality game developed by Niantic that encourages low intensity, movement based physical activity. Niantic is a software

development company that is known for developing augmented reality games that use geolocation and real world data. Niantic's goals with the implementation of *Pokemon Go* is to create a game that encourages healthy outdoor exploration and social interaction [2]. We selected this game due to its international popularity as it is still very popular in the current year of 2021. *Pokemon Go* has an estimated current player base of 166 million people as of 2020 [28]. With such a high player count, Pokemon Go can be looked at for inspiration and guidance for how to draw in and retain players.

6.3.1 Physical Activity

Pokemon Go as defined in a previous chapter is an exergame. Without the use of external modifications, *Pokemon Go* requires its players to travel the real world by means of human powered transportation to complete objectives as directed by the game. However the exercise encouraged by the application is of low intensity and is a consequence of the use of geolocation technology. Two studies we found, published in 2016, after the release of *Pokemon Go* note that there is a significant short term increase in physical activity in the form of total dialy steps taken after the installation of *Pokemon Go*, [11, 26]. We currently do not know if the increase of light physical activity persisted over the lifetime of the game. Though the game gives players opportunities to move, exercise within *Pokemon Go* is optional and not required of the player. In our experience, it is possible for a player to not exercise and still engage with the game.

6.3.2 Game Mechanics

The core gameplay loop in *Pokemon Go* revolves around the player traversing the real world and capturing pokemon. There are mechanics that support the physical activity in the game such as landmark locations that grant players additional items to use in game. There are many mechanics that do not impact the physical aspects of the game as well - such as the actual act of capturing a pokemon with a pokeball. There are pokemon battles such as gym battles that allow players to use the pokemon they captured. Missions are available for the player to complete for more opportunities to get the items required to capture more pokemon. The resources used to capture pokemon are limited and thus there are times when the player is unable to catch pokemon.

A large portion of the game mechanics, such as battling other players, trading pokemon and gifting, reinforce the social aspect of the game.

Figure 6.9: A screenshot of capturing a pokemon named Weedle in *Pokemon Go*.

6.3.3 Motivation

Pokemon Go motivates its players to move by providing goals set in the real world. This requires the player to set out and explore their environment making the exercise achieved a consequence of this design and technology. This includes the pokemon out in the world, pokestops for item collection, pokemon gym battles and objectives/research provided by the game. The game focuses on retaining players through a consistent goal and reward loop that happens at different time intervals. In figure 6.10, demonstrating the field research objectives, the player is given tasks to complete and is rewarded for completing one a day. Progress is tracked so if a player were to miss a day their prior efforts would still be recorded. This gives every action a player does within the game some form of reward.

Figure 6.10: A screenshot of the field research objectives provided by the game.

6.3.4 Adaptation

As a game, *Pokemon Go* offers a lot of personalization with respect to the player's avatar and representation. There is also the option to reroll field research objectives, potentially obtaining one more achievable given the player's circumstances and environment. In terms of game difficulty, there are no options for adapting the games mechanics to the player. This is also true for the physical aspect of the game. For example hatching pokemon eggs within *Pokemon Go* requires the player to walk set distances depending of the egg. Fortunately, player achievement is accumulated over all player actions and even if players are not as physically active, over a longer duration of time the more distance intensive pokemon eggs can still be hatched. In *Pokemon Go* are encouraged to explore and engage with physical activity to make the most of their *Pokemon Go* experience. Every player engages with the same set of mechanics in the same way. What the game lacks in game adaptability, it makes up for by having many features the player can partake in to further

personalize their experience.

One interesting design choice is how the game adapts to player groupings as a whole. Pokemon will be created in the world based on the amount of players in a given area. The more players there are in the area, the more pokemon will be spawned into the game world. This significantly reduces the amount of available actions a player has based on the player density of the area they live in. A trend being that more densely populated cities with more players and therefore more pokemon require players to move around less to achieve the same level of achievement for the core gameplay mechanics.

Figure 6.11: A screenshot of a player's inventory of pokemon eggs to be hatched.

6.3.5 Pokemon Go Analysis Conclusion

Pokemon Go is an incredibly successful exergame simply based on its ability to draw in a retain a player base. However as noted by [59], the success of game can be attributed to the nostalgia generated by the brand, the novel mainstream use of "new" technology in combination with a well executed social activity. As an exergame, *Pokemon Go* does not focus on the act of exercise. It does show how exercise can be encouraged through the use of a social environment and game-assisted goal setting.

6.4 Ring Fit Adventure

Ring Fit Adventure[3] is an exergame published by *Nintendo*. We selected this game to analyze due to its exercise-focused design and popularity. It is also the only game being analyzed that tracks and uses a variety of different physical exercises. Though that is different from Cyclescapes, we can draw inspiration by looking at how each exercise is tied into the game as a whole.

6.4.1 Physical Activity

The exercise in *Ring Fit Adventure* consists of jogging and a variety of other exercises. The game itself takes the player through a structured exercise routine. In figure 6.12 a player is demonstrating squats during the battle portion of the game. The exercises performed by the player is measured and tracked by the *Nintendo Switch*'s joy cons. One joy con is strapped to the player's leg and the other is attached to a ring like controller extension as seen in figure 6.12, hence the name of the game. The ring itself provides resistance when being compressed, which is used in many of the assigned physical exercises. The design of the exercises used in *Ring Fit Adventure* were done in conjunction with a personal trainer and a yoga instructor, as outlined in the frequently asked questions section of their website [3], `https://ringfitadventure.nintendo.com/faqs/`. The total variety of exercise movements available in the game sum up to 60 unique movement types. With respect to exercise, the game also takes safety into account, each movement a player must do is accompanied by a movement guide that describes how the movement should be done. This is done through an on screen animated tutorial.

6.4.2 Game Mechanics

There are two modes in *Ring Fit Adventure*. The first is adventure mode. This mode takes the player through a narrative where the player must run through different levels and different worlds battling against monsters and ultimately defeat the antagonist of the story, Dragaux. To progress through each level the player must run in place, squeezing the ring controller to release blasts of air to destroy obstacles and jump, while pulling apart the ring controller to collect items found throughout the game world. If a player encounters an enemy within a level, they initiate a turn-based battle system. The player must perform specific exercises to attack and defend against the enemy creature. This cycle is repeated until the enemy runs out of hit points and the running resumes. At the end of each world the player battles against Dragaux in a similar style to the regular enemy battles. If a player is defeated in a battle

Figure 6.12: This is a promotional image for Ring Fit Adventure released by Nintendo.

the level restarts. Throughout adventure mode there are also side missions and additional objectives that the player can complete. Some objectives like the battles are not optional and if not done force the player to restart the level. The second mode of interest allows the player to play an assortment of minigames in the form of a custom workout. The intent for this game mode is to give players an additional option for exercising and gaming even after having completed adventure mode. The challenges implemented focus directly on the exercise employed by the game. Each challenge requires the player to perform an exercise movement, such as running in place to traverse the level. Player progression is also present in the game's adventure mode. As the player completes more levels they unlock harder hitting attacks for battles which translates into more difficult exercise movements.

6.4.3 Motivation

Ring Fit Adventure assumes that a player approaching the game wants to exercise. Therefore there is a greater focus on maintaining and gamifying exercise. From our analysis of *Ring Fit Adventure*, the game uses constant feedback to encourage the player to keep moving. It also offsets the goal setting to the system side which allows players to track their own progress and improvement. We find that the approach the game takes to motivate a player mirrors the experience one would get with a personal trainer. With clear instructions and words of encouragement the player is always shown how to complete each exercise. The game then allows the player to challenge themselves with more difficult exercises giving the game a sense of constant challenge. The personal trainer experience combined with the gamification of

goals is how *Ring Fit Adventure* motivates its players to keep on exercising.

6.4.4 Adaptability

In the spirit of being inclusive, there are many options in *Ring Fit Adventure* that show it having strong adaptability. It should be noted that of all the information we could find, there was no mention or details of any system side, behind the scenes adjustments. All changes made within the system seem to be manually controlled by the player. There is an initial setup test the game provides to assess the player's capabilities. It asks questions to determine what level of fitness a player is at and sets the games starting difficulty with respect to the received answers. Players have the option to adjust the level of difficulty manually on a 1 through 30 scale as depicted in figure 6.13. Further more, the game provides accessibility options in the form of an assist feature. This can offset the difficulty of the game with respect to specific exercises for players unable to perform the required movements. It is important to note that not all exercises within *Ring Fit Adventure* make use of the assist feature.

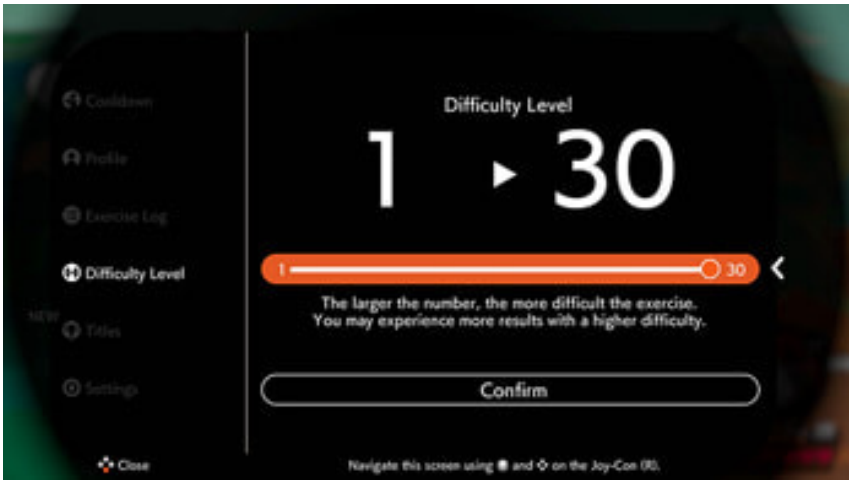


Figure 6.13: This is a screenshot provided by Nintendo on their *Ring Fit Adventure website referenced above.*

The game provides a custom workout mode allowing players to customize their workout routine with their desired exercises and also has a quick play mode for players with less time in their day for a full exercise routine. The most interesting mode that is available to the player is the multitasking mode. This mode tracks a players push and pull with the ring. Registering a full push or pull as a single repetition. This allows players to multitask exercise with other activities they may be doing, like chewing gum for a jaw workout. The multitasking mode tracks up to 500 repetitions at which it turns off the

switch's joy-cons, stopping the game mode. This mode allows players to perform physical exertion at their own pace throughout the day. Adapting to more busy life styles.

6.4.5 Ring Fit Adventure Analysis Conclusion

Ring Fit Adventure is a strong exergame. Following the traditional *Nintendo* game design branding, *Ring Fit Adventure* is designed to be easily accessible by a large demographic of players. It also demonstrates a focused design with respect to exercise evident by the consultants used to design the motions used in game. The game does well in abstracting what forms the basis of intensity for its movements thus allowing more adaptability in exercise intensity. The cool narrative serves as a method of engaging players not as interested in the exercise. It is evident that *Ring Fit Adventure* has a good balance of game design and exercise noted by its 11.26 million sold units reported in this 2021 year end financial results report by *Nintendo*[8]. The game is also well-received and praised for its ability to provide a largely sedentary audience an encouraging means of engaging in physical exercise as seen in the following video game reviews [24, 36, 31]. Understandably the reviews in question are not academic and scientifically rigorous but they offer a glimpse into consumer perspective with respect to the implementation of *Ring Fit Adventure*, which can be used to better guide our design decisions for Cyclescapes.

6.5 Hot Squat

Hot Squat[1] is a VR exergame. We chose to take a closer look at this game due to its positive review on the Steam storefront, its relative poor performance in this VR exergaming study [66], and its design that is similar to Cyclescapes's constraints. This game was also more accessible due to its zero dollar price tag. The game is about squatting to fit into a cutout in an incoming wall. Unlike the game show *Hole in The Wall*, the shape of the hole is constant, what varies is the duration a position must be held.

6.5.1 Physical Activity

The physical exercise used in *Hot Squat* is the squatting motion. The exercise is tracked through the tracking of the VR head mounted display. The game requires the player to squat for varied amounts of time. As the game progresses, incoming walls approach more quickly and frequently requiring the player to squat more often and more quickly as they get better at the game. Based on the player feedback obtained from the *VRmove Framework* study [66], the

motion of going to squat position from standing and back to standing evoked a more intense perceived physical workout.

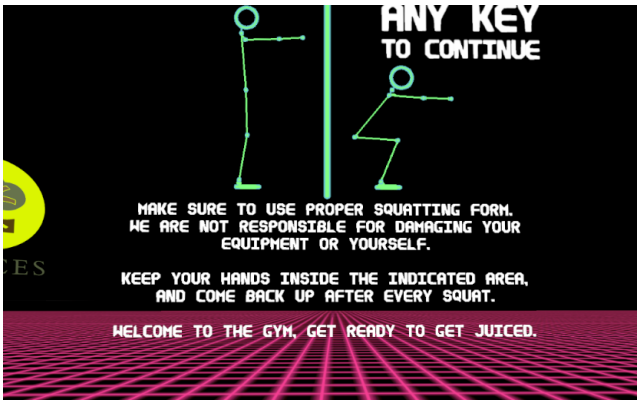


Figure 6.14: This is a screenshot of the instructions provided by *Hot Squat* at game launch.

With respect to safety and exercise guidance, the game does offer a short instructional picture like those found in *Ikea* DIY booklets for furniture when the game launches as demonstrated in figure 6.14.

6.5.2 Game Mechanics

The game mechanics in *Hot Squat* are focused around forcing the player to perform the squat exercise and to perform it often. The objective of the game is to squat as many times as possible throughout a potentially endless game. The game sends waves of barriers towards the player with a small gap of time in between for a break. To pass through the barrier the player must squat and then return to a standing position. Each repetition of a squat counts as 1 towards your score. The final score of the player is determined by the number of complete squats a player has completed until failure. Failure for *Hot Squat* refers to a collision with the wall while not squatting. As the player continues to play, the higher the score the more difficult the game becomes. The difficulty of the game challenges are very deeply tied to the physical exercise required of the player. The barriers that approach the player all require the player to squat to the same height, this for exercise consistency but the amount of time a player must stay in the squatted position can vary. For players who are claustrophobic or can not handle being in enclosed spaces, *Hot Squat* may be uncomfortable. This is due to the size of the space in the barrier/wall that approaches the player being very form fitting to the player's head in vr space. It envelopes and blocks a significant portion of the player's side field of view like a tight tunnel.

6.5.3 Motivation

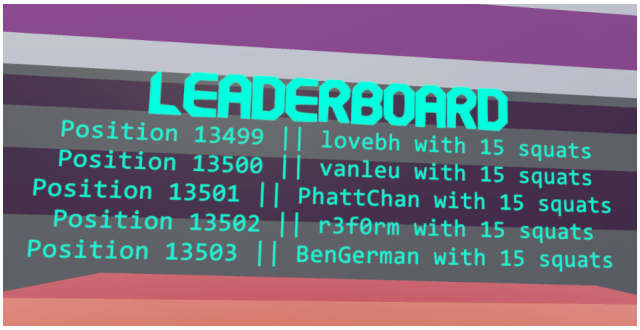
The game's design demonstrates a design for a player that is playing to exercise. This is evident by the design of the virtual game environment as well as the hyper focus on squatting. The game in no way hides what motion the player is doing and rather closely intertwines the exercise to the core function of the game. The game's most apparent methods of driving player movement is the squat counter and global score leader board as seen in figure 6.16. The squat counter, seen in 6.16a off loads tracking player score to the system, allowing players to better track progress towards personal goals. The leaderboard encourages player movement by providing a small social outlet for competition between different players. The number of squats performed by the player is also attached to achievements within the *Steam* digital distribution ecosystem of games. For example, the "Golden Gluteus" achievement in figure 6.15 rewards players for performing 175 squats in one round of the game. This number is many times greater than any normal workout yet with *Steam*'s statistics it can be seen the 7.6% of all players who have played *Hot Squat* have accomplished this goal.

Figure 6.15: An achievement on *Steam* completed by playing *Hot Squat* and performing 175 squats in one round of the game.

One questionable method of motivating the player to move that has unclear benefits or negative effects is the automatic restart after a game is complete. When the player eventually loses their current run through of *Hot Squat*, the game will provide the player some time to recuperate but is quickly followed by the first wave of barriers. For players of *Hot Squat* this may be inconsequential as any players that wish to stop playing can simply remove the head mounted display and turn off their VR system. However whether or not this design choice encourages players to move in an exergame can be tested.

Outside of goal setting, competition and automatic repetition, the upbeat music in *Hot Squat* offers an energy that is reminiscent of 80/90's workout music. The beat follows closely to the tempo of squatting required of the player.

(a) The counter of squats completed on the back of the player's hand.



(b) Leader board for *Hot Squat* for players from all over the world.

Figure 6.16: Score goal keeping features in *Hot Squat*.

6.5.4 Adaptability

Through our investigation into *Hot Squat*, we came across no features that adjusted the game's challenge difficulty and exercise difficulty to match the player's physical fitness and gameplay ability. The changes in game difficulty comes with player progression and improvement to muscular endurance. The player must adapt to the game in order to get a better score rather than the game adapting to the player to make achievements easier. For the purposes of usability, the game does automatically calibrate to the player's height at the beginning of every run of the game. This is done to ensure the player lowers themselves the proper assumed amount to perform a proper squat.

6.5.5 Hot Squat Analysis Conclusion

Hot Squat is a very focused game, focusing on the movement of squatting. The game uses gamification features to encourage the player to exercise. In a term, the game is exercise driven. The game understands who would want to play it and is not designed to be fun for everyone. The gameplay loop is repetitive and reliant on competition between players, music and an automatic repetition to

drive player movement. On steam the game has a rating of *"Very Positive"*, with 92% of its 140 user reviews giving it a positive score [1]. The review provided by the study for the *VRmove* framework [66] demonstrated that out of the games reviewed in that paper, *Hot Squat* provided less enjoyment and was the most physically taxing. From looking at the design of the game, *Hot Squat* is a game intended for a player already wanting to exercise and improve their own physical fitness. A general audience such as the one recruited by the *VRmove* study may be less likely to receive the game as well. Therefore, *Hot Squat* is well designed exergame for players who want to exercise with features tailored for the competitive exercise enthusiast. The features employed may not be enough to retain the interest of a general audience.

6.6 Analysis Summary

Table 6.1 is a summary of the characteristics of the games analyzed in this chapter as follows:

- Platform - Where the game can be found and played.
- Tracking - How the game recognizes exercise
- Movement - What movement is required of the player in order to play the game.
- Game Focus - Refers to exercise driven and game driven definitions above.
- Adaptability - What aspects of the game can be adapted to the player.
- Motivation - What features of the game are used to encourage player exertion/exercise.

Similar to the findings made by Farič *et al.* and analysis done by Yoo *et al.* we have found that there are many factors that make a commercial exergame a a good game and also a good alternative to traditional exercise. The far right column in table 6.1 is a summary of the features we found to factor into motivating players to engage in exercise.

Title	Platform	Tracking	Movement	Focus	Adaptability	Motivation
Pokemon Go	Mobile	GPS, Pedometer	Walking	Game Driven	None	Social Gameplay, Real World Exploration, Creature collection
Zombies, Run	Mobile	GPS, Pedometer	Running	Exercise Driven	Optional Mechanics, Variable session duration, Variable session distance, Player speed feedback loop	Narrative, Resource collection
Ring Fit Adventure	Nintendo Switch	Ring Con, Switch's Joy Con	Varied exercises	Exercise Driven	Accessibility options, Difficulty selection	RPG Player progression, Encouraging feedback, System Guidance, Goal tracking/management, Different Play Modes
Hot Squat	PC, VR	VR HMD	Squats	Exercise Driven	Success based difficulty increase, Player height calibration	Leaderboard, Music, Goal Tracking, Achievements

Table 6.1: Summary of analysis of games reviewed in this chapter.

6.6.1 Design Lessons

Through the analysis of 4 games in this chapter across different modality we have gained some insight into how Cyclescapes should be designed with respect to its game challenges and physical fitness challenges.

Movement Variety

Movement in an exergame should have complexity to it. Characteristics that can alter the movement for the player such that it isn't just a monotonous repetition of actions. The game in our analysis that we feel best demonstrates this is the game *Hot Squat*. Throughout a single run of *Hot Squat* the game forces the player to hold their squat for extended periods of time, repeatedly squat in quick succession and even allows the player small breaks in between squatting. The design choice of adding movement variety keeps the player engaged and reactive to the prompts of the game - ready to perform the next action or change to their current action as required by the game.

Achievement Tracking

An exergame having means of measuring the player's performance is a good design starting point. It is important that the achievement being conveyed to the player is also easy to understand. This provides the player a method of determining their own performance and creating their own personal goals such as self improvement. *Hot Squat* demonstrated self improvement through its simple squat counter and positive player sentiment is a viable means of encouraging the player to exert more.

Difficulty Control

The difficulty of the physical challenges in an exergame should allow for manual alterations. This will accommodate players that want to challenge themselves and for players who are not so confident in their physical fitness capabilities. On top of manual control, a player's physical performance should also be taken into account. Combining the 2 aspects of manual and dynamic difficulty control for physical exertion challenges will allow the exergame challenges to more accurately reflect the player's desired difficulty as well as ability.

Features

When designing Cyclescapes all mechanics related to the player side of the game's design should facilitate and encourage physical activity. The challenges should explicitly test the player's ability to pedal. This does not mean that the exergame cannot have mechanics or features that do not require exertion of

the player but there should be a means of connecting the game mechanic and goal to the exercise. A good example of this is the base building in *Zombies, Run!*. A player requires resources to expand their base, see figure 6.7 but in order for the player to collect resources they must complete a mission, and a mission requires the player to run.

Chapter 7

Metrics

To better capture the effects of our Cyclescapes implementation we need to systematically define what we are trying to affect and follow up with defining how we aim to measure it. Referring to the problem statement as stated in chapter 1, we want to answer; *how a game that mandates physical exercise can be adapted to the physical abilities and gaming abilities of the player such that the player is encouraged to move*. There are three parts to this question, the physical fitness of a player, the gaming abilities of a player and the ability of the system to encourage players to move.

7.1 Physical Fitness

For the purposes of Cyclescapes and our research question, we need to assess the physical fitness of a player. To understand the individual player we must have a means of gauging their exercise intensity with respect to the exercise required of them through the Cyclescapes game. As defined in chapter 3, exercise is structured physical activity. Physical activity refers to any action or movement produced by skeletal muscles that cause energy expenditure/exertion by the participant. Exercise intensity is unique to an individual and describes the relative difficulty of the exercise and in general, the more a player is required to exert the more physically intense their exercise becomes. For Cyclescapes, exertion is required to be achieved through means of pedalling on a bicycle trainer.

7.1.1 Measuring Physical Exertion

To measure the amount exertion being accomplished by the player, as introduced in chapter 3, we must be able to capture the the player's exercise intensity throughout the game. There are two methods to conveniently assess the level of effort a player is putting forth during the duration of the game.

The first method is measuring the player's heart rate. Heart rate data can be used to continuously monitor heart rate and obtain average heart rate. The second method is by measuring the player's power. This can be continuously monitoring the player's instantaneous power or collecting the average power output throughout a given session. Heart rate monitoring has seen commercial use as well, in *Ring Fit Adventure* [3], At the end of every level the player is given the option to measure their heart rate through the use of the infrared sensors on the *Switch*'s *Joy Cons*. The player is then told based on their heart rate and inputted age what level of exercise is being achieved. Similarly, for Cyclescapes, we can constantly measure the heart rate of the player and match against a heart rate maximum - provided by the caretaker or player. This will allow us to more accurately gauge the player's level of physical intensity relative to their own expected physical fitness level. To answer the question posed by the problem we are exploring, we do not require a the observation be specific to the level of exercise intensity demonstrated, therefore monitoring and addressing more general elevations in heart rate will be enough to determine whether or not a player is experiencing an increase in exercise intensity. For monitoring the power output of the player on the cycling trainer, we are able to measure and quantify the amount of effort the player is doing for the workout [16, 37]. The measure of power is done through the trainer that the player will be pedalling on and is measured in Watts. The power measured by the system is a snapshot of the power the player is outputting at any given moment. By monitoring the power of a player at any given moment we can assess differences in the quantify the effort a player is outputting. Power is also a commonly used metric for cyclist for performance analysis [37]. Furthermore, we will be able to analyze and record average power and heart rate output of the player and approximate the effort achieved during a whole session. Using heart rate monitoring, maximal heart rate comparisons and monitoring player power output will allow us to determine the level of exertion that the player is achieving and more importantly determine what effects our implementation of Cyclescapes has with respect to a player's exertion during the game and over time with continuous play.

7.2 Gaming Ability

We are defining **Gaming abilities** as the ability of a player to overcome the challenges presented by a game. Cyclescapes as a game focuses on physical coordination challenges as defined by Adams [9]. The challenges found in exergames do not entirely map to the definition of each challenge type defined by Adams, this largely due to Adams' definitions to be more tailored towards traditional gameplay. However the challenges found in exergames are similar enough that only a slight modifications are needed. In table 7.2, there are 2

Challenge	Definition	Example	Related Challenge
Speed Burst	A challenge that requires a significant increase of exertion from the player due to an increased frequency of input.	Zombies, Run	Speed
Movement Matching	A challenge that requires the player to move in a specific way.	Ring Fit Adventure	Accuracy and Precision

Table 7.2: Table summarizing the Physical Coordination Challenges as presented by Adams with modified definitions to better fit exergames The related challenge column refers to what Adams challenge it derives from.

Challenge	Definition	Example
Power	A challenge that requires increased exertion due to external resistance.	Ring Fit Adventure
Endurance	A challenge that requires prolonged or repetitive movement of the player.	Hot Squat

Table 7.3: Table summarizing the Physical Fitness Challenges exclusive to exergames with respect to traditional games.

different challenges related to physical coordination as defined by Adams. The modifications of the two challenges adapt the existing definition to an exergame context. In table 7.3 are 2 challenges that are not described by Adams as that represent the interactions only found in exergames. It is important to understand that game challenges found in exergames also have access to the traditional game challenges and are not limited to the ones In tables 7.2 and 7.3.

7.2.1 Measuring Gaming Abilities

The method to measure a player's ability to overcome a game challenge is dependent on the implemented challenge. For this reason the scope of measuring game abilities will be limited to the challenges implemented for Cyclescapes.

The objective of Cyclescapes is to collect as many gems as possible during the duration of a session. Justification and further detailing with regards to design choice can be found in later chapters of this thesis. The purpose of this

section is to describe how we will measure the gaming abilities of a person playing Cyclescapes. There are 3 major challenges in Cyclescapes and 2 less obvious challenges that layer on top of the major 3.

The base challenge is an endurance challenge. Throughout the course of game, along the route used by the player will be gems that dot it like a cookie crumb trail as depicted in figure 7.13. The greater the amount of gems collected for the final score approximates distance pedalled by the player, modelling the degree of success the player had with the endurance challenge.

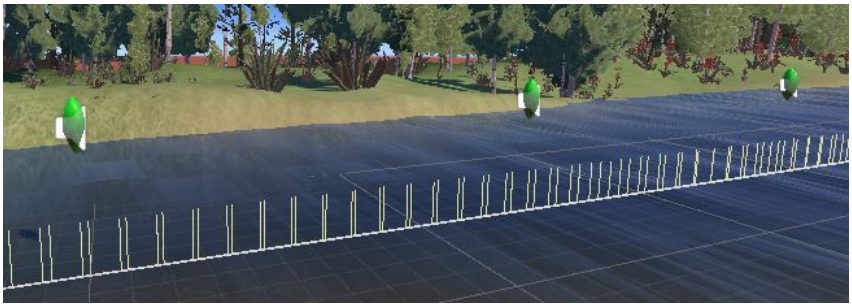


Figure 7.13: How the base challenge is created in the game world.

There is a speed burst challenge that comes in the form of an increased speed gem. This gem is of higher value than the base gem and requires the player to pedal at a percentage speed faster than their current speed. The degree of success for this challenge is tracked by means of missed collections and successful collections.

Movement matching is the third major challenge implemented in Cyclescapes. This challenge requires the player to control their in-game speed and match the speed of the special challenge gem. The degree of success a player has with this challenge is measured by the number of missed, partial and full collection connections with the movement matching gem.

The 2 modifier challenges that layer on top of the 3 major ones are a strength challenge and a more traditional beating the clock challenge. The strength challenge comes in the form of resistance provided by the bicycle trainer device. It adjusts itself based on the selected route. The resistance changes based on the slopes of the route. The beating the clock challenge refers to the limited time available for the burst speed and movement matching major challenges to be completed. Both modifier challenges will make getting a higher score more difficult.

All 3 major challenges contribute to the final score as they all are a method for the player to collect gems that contribute to add up to the final score. Thus a general means of measuring the level a success a player has with the game and their competency relative to Cyclescapes' challenges is by comparing their final score against a baseline that has yet to be determined.

7.3 Encouragement

The core of the problem we wish to explore within this thesis, we will define **Encouraged to Move** as the willingness of the player to willing exercise within the game. When a player is encouraged to move the perceived exertion can change and may not match the actual exertion being performed [66]. The foundation of defining encouragement is by comparing the quality of effect provided by the means of encouragement and observing how much more the player moves due to the stimulus implemented within the system. Monitoring how changes to the game's challenges alter the intensity as well as their enjoyment during a session.

7.3.1 Quantifying Enjoyment

To properly compare the effects of our implementation we need to establish a baseline that is achieved by the player.

This can be done by making comparing the effects of each mechanic or feature on the player's enjoyment or physical performance.

For the purposes of limiting scope and staying true to the original purpose of the project there should be two activities to use for comparison. The first being sedentary treatment of the player/patient. This is the traditional treatment done for patients targeted by the Cyclescapes project where there is no physical activity. The first activity is to assess the enjoyment of our Cyclescapes implementation when compared to the status quo treatment.

The second and most important activity the Cyclescapes implementation must be compared to is pedalling on a stationary bike without the use of game mechanics or VR technology. This comparison is done to assess the difference in enjoyment and as well as physical activity levels. The points of comparison outlined in this section can also be applied to future Cyclescapes iterations to better refine its design and the effectiveness of new features.

The more straightforward activity to measure for a comparison between pedalling on a stationary bike and using the Cyclescapes system is the difference in physical exertion. As mentioned in section 7.1 of this chapter physical exercise intensity can be measured through a player's heartrate and effort can be assessed through the power output of the player. To make a greater comparison between all participating parties, the data should be normalized against each metric to remove individual variation and to better assess the effects of the system on a general demographic. The activity of designing a video game and thus an exergame is complex, for this reason the test should be run many times to account for sub optimal user interface design as poor design choices in UI, sound and visual design can lead to a poor player experience [9]. What these player experiments should focus on are the effects of the game challenges

and design on physical exertion. Then by comparing the difference in exertion we can get a better sense as to whether or not the game challenges chosen encouraged physical activity based on the potential increase or decrease in heart rate and effort.

The more difficult attribute to assess is a player's subjective enjoyment of our system implementation. In [66] they use a 7 point Likert scale to measure enjoyment, where 1 meant a game was very boring and 7 being high enjoyment. This scale is appropriate but for the purposes understanding the potential failures and successes of Cyclescapes we need more points of data rather than the overly broad enjoyment term. The *Exergame Enjoyment Questionnaire(EEQ)* [22] provides a template for potential questions that can be given to participants post playing a session of Cyclescapes to understand their feelings towards the game. The questionnaire operates on a 5 point Likert scale. Participants select a response on a scale ranging from *Strongly Disagree* to *Strongly Agree* for each statement on the questionnaire. Figure 7.14 is a list of all questions belonging to the original questionnaire. The survey totals up points, where a higher point total equates to a more enjoyable experience by the participant/player. For questions 1, 2, 3, 5, 7, 8, 12, 14, 15, 16, 17 and 20 refer to table 7.4. For questions 4, 6, 9, 10, 11, 13, 18, and 19 refer to table 7.5. For acquiring more specific feedback with respect to the design of the game overall player thoughts should also be recorded for later analysis. During player testing if the questions in the *EEQ* are found to be lacking more specific questions can be added following the same format. Positive statements with respect to the Cyclescapes experience should use the point assignment as outlined on table 7.4 and negative statements should follow table 7.5.

Answer	Points
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

Table 7.4: Point assignment for positive questions in the Exergame Enjoyment Questionnaire

Answer	Points
Strongly Agree	1
Agree	2
Neutral	3
Disagree	4
Strongly Disagree	5

Table 7.5: Point assignment for negative questions in the Exergame Enjoyment Questionnaire

The potential problem with a questionnaire this detailed is the audience being targeted by the game, especially the younger children of the audience, may have a difficult time providing answers exactly in this form due to their education level. Conversely, simply asking their opinions may not yield sufficient information or be focused on game design elements. Ideally, quantifying game engagement and enjoyment would rely on a combination of quantitative questions, 7.14, as well as qualitative questions to better understand the quantitative findings.

1. I felt excited for physical activies in the game.
2. The exercise in this game made me feel good.
3. I felt like a lost track of time while playing.
4. I felt like it was difficult to understand how the game works.
5. I was focused on the game.
6. I felt that the game would be more enjoyable without physical activity.
7. I felt that it was easy to familiarize myself with the game controls.
8. I felt emotionally attached to the game.
9. I consider playing the game "exercise".
10. I felt that the physical activity was too intense for me.
11. I did not feel a desire to make progress in the game.
12. I felt a strong sense of being in the world of the game to the point I was unaware of my surroundings.
13. I would rather not be exercising, even though the exercise was accompanied by game elements.
14. I felt that playing the game was beneficial for my physical well-being.
15. I felt that this game provided an enjoyable challenge.
16. I felt a sense of accomplishment from playing the game.
17. I felt that the game reacted quickly to my actions.
18. I did not feel like I wanted to keep playing.
19. I would prefer that this physical activity was not accompanied by game elements.
20. I felt in control of the game.

Figure 7.14: The Exergame Enjoyment Questionnaire [22].

Chapter 8

Cyclescapes Requirements

The system requirements presented in this chapter and section will concentrate on the game aspect of Cyclescapes, ignoring the data collection side of the system if it does not interact with or fulfill player goals and requirements. The focus of this thesis is on the challenges of the game and subsequently the rules, goals and gameplay. Therefore the data collection aspect of the project will have little to no impact on the requirements of the game. However, because the two subsystems are intertwined there will be some aspects of the data collection subsystem that will find its way into the game's requirements. These will be marked as such to further justify why certain decisions are made in chapter 10.

8.1 Game Design

The most important aspect for the design of Cyclescapes when exploring challenge and motivation with respect physical and game challenges is the design of the gameplay. Gameplay is composed of actions and challenges. Refer to section 4.3 for the definition we are using for *challenge*. Adding to gameplay are the rules and goals of the game. The rules of a game define how the challenges in gameplay can be interacted with by the player. The goals of the game provides purpose to player actions. Without a clear goal, the challenges in gameplay have no meaning. More formally, we will define rules, goals, actions and challenges as they relate to the requirements of Cyclescapes.

8.1.1 Rules

The rules of a game define the game. The rules of a game contain the instructions of how a game is played. Related to defining the pretend reality described in the Pretending section of this chapter. Rules define the boundaries of play and the virtual world of our games.

For Cyclescapes, the rules need to be designed with the core goal of the project as well as our research in mind. The rules must facilitate the movement and exertion of the player when playing Cyclescapes. The exploration of rules will also be a vein of investigation worth looking at with respect to the research problem.

8.1.2 Goals

The goals of a game refers to the goal a player is trying to achieve within the confines of the game. The goal of the game is outlined within the rules. A key idea behind goals defined by Adams is that a goal need not associate with the ideas of loss or victory. A goal is simply something a player needs to accomplish or actively pursue. It must be noted, for the purposes of our research and Cyclescapes, we are not considering goals external to the sysetm, created by the player but rather focusing on goals provided to the player through the system. For example, the system will not facilitate players competing with respect to a high score.

For the purposes of Cyclescapes, goals should be used as a means of moving the player along, getting the player to engage with the exercise. We must consider and explore different potential goals that can be used within the game to get a sense of which player goals better achieve our objective.

8.2 Cyclescapes Review

Before discussing the end use environment for Cyclescapes it is important to understand and reiterate what the project is trying to achieve as a product outside the research and academic space. Cyclescapes is a product intended to help people who live sedentary life styles due to medical treatment obtain a higher health-related quality of life by means of physical exercise. By providing players a method of entertainment that incorporates physical activity, Cyclescapes hopes to motivate players to achieve their physical fitness goals in fun, gamified way. The end goal of all future and possible iterations of Cyclescapes is not limited to the patient group targeted by the research being conducted by the pediatric researchers.

As mentioned in chapter 2 the base of the requirements for Cyclescapes, mandated by the "*clients*" of the project, the pediatric researchers of McMaster's Children's Hospital. Cyclescapes must be game, must make use of VR technology, must make use of a bicycle trainer as the main form of physical activity interaction, must make use of real world data and must be themed such that it is appropriate for a varied age demographic. As a caretaker's tool, Cyclescapes must give caretakers the ability to monitor patient status while playing the game. We are avoiding covering research-related aspects of the

requirements for Cyclescapes as they are more distantly related to the topics in this thesis.

8.3 Anticipated Use Environment

As of the writing of this thesis, the anticipated use of the Cyclescapes game is for patients receiving hemodialysis or peritoneal dialysis treatment at McMaster Children's Hospital. Following this expectation, this section will breakdown in detail the anticipated use environment, who will be using Cyclescapes as a product, the required hardware to play the game and how VR will have an impact on the requirements of the system.

8.3.1 Anticipated Users

There are two users we expect to use Cyclescapes. The primary user is the patient/player. The second is the caretaker. Each user will be interfacing with Cyclescapes for a different reason. This section will detail an expected profile of each user and how we think they will be interacting with the system.

Patient/Player User

The patients that will be playing the game fall within the range of the following characteristics:

- **Age:** 6 - 18
- **Gaming Experience:** No Gaming Experience - Consistent Gamer
- **Physical Fitness:** Completely Sedentary - Physically Active
- **VR Experience:** None - Experienced

A standard dialysis session requires the patient to sit or lay down and they are connected to a dialysis machine by catheters. The dialysis machine will draw blood from the patient, filter the blood, and return it to the patient. This process takes 3-5 hours, and is repeated 3 times per week.

A standard dialysis session as explained by *Dr. Obeid*, requires the patient to sit or lay down and they are connected to a dialysis machine by catheters. The dialysis machine will draw blood from the patient, filter the blood, and return it to the patient. This process takes 3-5 hours, and is repeated 3 times per week. Entertainment during such sessions are traditionally sedentary and may include watching shows on a TV, reading or engaging with handheld video gaming devices such as a *Nintendo Switch* or a smartphone. The following is what we intend to be the general patient/player story when using Cyclescapes.

With Cyclescapes, the patient would come into the clinic as they would a normal treatment session. Once the patient is comfortable and dialysis treatment is underway, the caretaker will work with the patient to fit the bike. A heart rate monitor will then be slipped on one of the patient's arms, already on and ready for use, then putting on the VR head mounted display, the patient would become a player, awaiting further instructions from their caretaker/treatment supervisor. Once the session parameters have been set for the player's ability both gaming and physical fitness related the game would be launched. The player would be notified of this in their new VR from within the head mounted display and the player would play the Cyclescapes game. During a session the player will be encouraged to achieve varying levels of physical exertion for the purpose of completing in-game objectives. All objectives presented to the player require the player to adjust their pedalling cadence. Similar to how the player will adjust to the game, the game will also adjust to the player, ensuring there is a constant physical game challenge for the player to complete. The player would feel the slopes and descents of the chosen route they are biking on, representing a potentially real route they may be familiar with. Once the gaming session is complete either by virtue of running out of time or completion of selected path, the player will have a quantifiable metric to understand their performance. Regardless of achievement, the game will celebrate the accomplishments of the player. On top of feeling the endorphins from the exercise, the player should be slightly fatigued and feeling accomplished after having completed a workout session with Cyclescapes. After taking off the head mounted display the player will get off the stationary bicycle and proceed with removing the heart rate monitor, returning it to the caretaker or some predesignated location. The player can now ask the caretaker to see their own performance while playing the game. This will show the player their score, along with other aspects of their physical performance such as speed and power and intensity based on heart rate. In subsequent sessions of the game the player will compete against themselves and old scores giving the player a sense of improvement.

Caretaker User

The caretaker users of Cyclescapes refer to the group of people overseeing the safety of the patient/players playing Cyclescapes. They will be a member of the patient's healthcare team, which might include a nurse administering the dialysis treatment, a physiotherapist, or a child life specialist. Therefore, the caretaker user will be interacting with the game Cyclescapes in a very limited capacity more concerned with Cyclescapes as a safety and monitoring tool. The caretakers using Cyclescapes will possess the following characteristics:

- **Gaming Experience:** None
- **Digital Literacy:** Low
- **VR Experience:** None - Low

The following is the intended story for users using Cyclescapes in a caretaker role:

A caretaker would start up Cyclescapes on the clinic's VR ready computer. They would ensure all necessary hardware elements are connected and ready for use. Then the caretaker will assist the patient onto the bicycle, as well as putting on the VR headset. Then the caretaker would configure the game to match the current player, configuring the required game parameters to the player's preference. When launching the game, the caretaker should ensure the player is comfortable and ready to go. Throughout the session, a caretaker should monitor the patient's available biometric information. This is to ensure the player's safety while exercising and receiving treatment. The most important aspect the caretaker should be able to monitor is the player's heart rate. If the player's heart rate is too high it could make the activity of Cyclescapes and exercise dangerous. The system should be able to inform the caretaker what threshold they should be looking for. After the game is completed by the player, the caretaker should be able to review the player's performance during the gaming session. The caretaker will also assist the player in removing the VR headset as well as getting off the bicycle. As Cyclescapes is an exercise game, it can be expected that the player will sweat and some of their sweat may transfer onto the VR headset padding. This should be cleaned between every session by the caretaker.

8.3.2 Hardware and Setup

During the development process of Cyclescapes, we used the a custom built desktop computer with the specifications found in table 8.5. We assume in the actual clinic environment that the computer used will be similarly built or equivalent in terms of processing power to be VR ready and most importantly

Component	Specification
GPU Agree	MSI GeForce GTX 1660
CPU	Intel Core i5-9600KF
Memory	16GB (2 x 8GB) 288-Pin DDR4
Storage	500GB SSD
Motherboard	ASRock Z390
Power Supply	Corsair CX Series 550

Table 8.5: Main computer specification for development computer for Cyclescapes.

able to run Cyclescapes with the intended performance. If the computer build used in the clinic is not built similarly we cannot guarantee the same experience as the one that was designed.

For the sensors and input devices, we are using the *Polar OH 1* for heart rate monitoring, *Elite's Suito* indoor bike trainer coupled with Garmin's USB Ant Stick. Based on our understanding, the hardware for the input devices can be switched out for any technology the uses Ant+ communication. For the bike trainer it must be capable of transmitting speed, power and cadence information. The bike trainer must also be able to adjust its resistance. Figure 8.2 depicts the bike-computer set up that was accessible during the design and implementation of Cyclescapes.

Figure 8.2: Cyclescapes Development Trainer Setup

Ant+ communication technology is not perfect and through our own trials during development we noticed the receiver's physical position with respect to the heart rate monitor and bike trainer can affect its performance. If the receiver is too far from the other Ant+ devices it will lose the signal rendering any input intended to be used by the game lost. This will hinder the intended

player experience and can be avoided through proper receiver placement. Ideally, the receiver should have a direct line of sight with the heart rate monitor and trainer and within range based on manufacturer specifications. For the Garmin USB Ant+ Stick, the range is 10 meters [7]. On top of signal drop out for the Ant+ receiver, there is also the constraint of input lag. Input lag from the trainer makes it such that sudden changes in player input such as an instantaneous and significant changes in the player's power output will take time to register. This will make it such that the game can not have challenges that require quick changes in player exertion over short time duration.

In terms of safety, it is critical the end user set up for the devices to be as organized as possible. Though this is not an aspect of the software directly, Cyclescapes has a responsibility with regards to safe usage and play of the game. With many wires and the moving mechanical system of the trainer and bike it is important to keep the mechanical area of the bike and trainer clear of external wires and communicate this information to the users.

8.3.3 Virtual Reality Setup and Usage

Which VR system to use is an important decision to make that will impact the final experience of the player and the caretaker. With the product vision for Cyclescapes as provided by *Dr. Obeid*, to create a system that is portable. Where set up time after moving the system between clinics is minimized. Therefore the most important part of a VR system must also be quick to set up. For the sake of monitoring though, the game must also display to a computer.

Chapter 5 discussed the considerations that go into to the creation and design of a VR game. This section will detail our intended and expected use of VR in relation to the use of Cyclescapes.

For the player, the VR headset will take away from their awareness of their actual surroundings. The player should be encouraged to limit their range of motion while on the bike and in VR. This will make it safer for unrelated parties within a potentially busy medical clinic and also allow the player to focus on maintaining their balance. The dialysis treatment done on the player population is done either through the arm or chest. McMaster specifically conducts their dialysis treatment through the patient's chest. However, with the vision of the project being to create a more generally applicable game it cannot be assumed that the patient will have access to both arms during treatment. This fact combined with the need to maintain balance and not disrupt a medical clinic environment means it is necessary to constrain game inputs away from current VR controllers. Players must have the ability to move their hands in ways that can help them keep balance and not disrupt treatment while not having impact on the game.

Another concern is motion sickness while playing the game. Motion sickness must be mitigated to create a more enjoyable player experience. If the players are unable to play our game due to motion sickness it will render Cyclescapes unable to accomplish the project goals. VR is meant to augment the underlying game and provide a sense of escape for the patient playing the game. Allowing the patient to escape their reality of being in a hospital to being somewhere else entirely.

The ergonomics of the VR headset will also be a limiting factor for the duration of play. Prolonged use of the headset can cause ergonomic stress to the player due to the weight of the VR head mounted display [62]. Comfort and usability of the VR system will also depreciate as the session goes on due to sweat build up and fogging of the head mounted display lenses.

8.4 Cyclescapes Use Cases

Cyclescapes has a clear divide of use cases. For the purpose of gathering and listing requirements within scope of this thesis there are two types of users. There is player and the caretaker. Both users interact with Cyclescapes in vastly different ways for vastly different purposes. For the sake of organization, we will explore and identify use cases of both types of users separately.

8.4.1 Player Use Cases

The purpose of Cyclescapes as a VR exergame is to engage the player/patient in a game form that will encourage them to exercise more. To interact with the game the player will use the controls available to provide input into the system. The input data required of the player will be their heart rate and physical movements. The VR interaction with the player is to capture the player's macro bodily movements, such as the sway of their body or the turning of their head. The player will use the trainer to convey the main aspect of physical exercise in Cyclescapes, their pedalling. Physical exercise will be required of the player if they want to complete the in game challenges provided by the system. The player completing challenges will adjust their score accordingly. The player will also use the game to help them set goals for themselves to accomplish. This requires the player to be able to view their objectives and relevant performance statistics.

Figure 8.3 is a use case diagram depicting how the player is intended to use Cyclescapes. The player use cases are derived by focusing on their interactions with Cyclescapes as a game and aims to capture all required interactions between the player and the game.

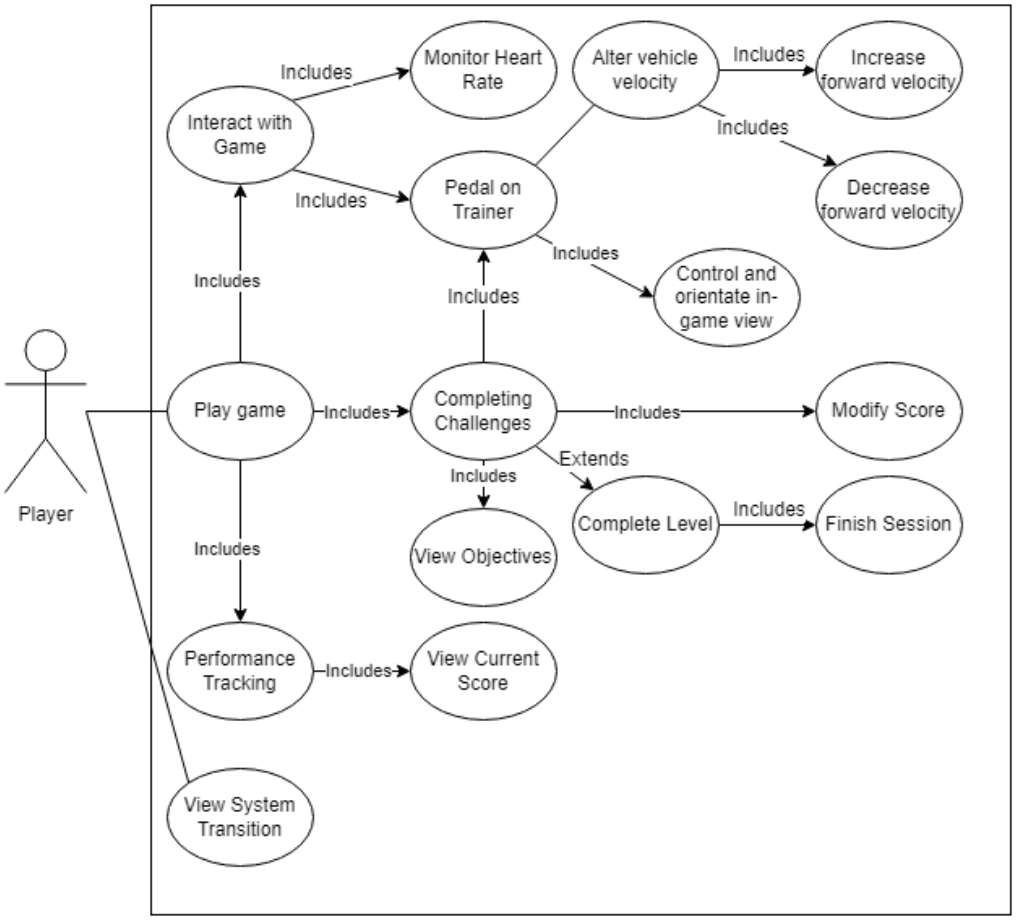


Figure 8.3: Player Use Case Diagram

Player Use Case Table

UC#	Title
P1	Forward Movement
P2	Speed Reduction
P3	Heart Rate Input
P4	VR Camera Control
P5	View Current Objectives
P6	Complete Challenges
P7	Modify Personal Score
P8	Complete Course
P9	View Current Score
P10	View Current Game State

Table 8.6: Summary product use case table for player actor.

8.4.2 Caretaker Use Cases

The role of caretaker is a mandated aspect of the project. During treatment, patients will be monitored by a nurse or other hospital personnel that fit this caretaker role. The responsibilities of the caretaker is to ensure the safety of the patient and the adjust the games for the patient should that be required. Cyclescapes should provide tools to make that job easier. Though not all aspects of the caretaker's use cases are related to the problem domain of this thesis most aspects do have a connection with the game and challenges in Cyclescapes. Figure 8.4 demonstrates all relevant uses cases with respect to the challenges, exercise and motivation of the player.

The caretaker's main task is to oversee the game session for the player. This will include configuring the session by altering and adjusting the different game parameters to meet the player's needs. Caretakers will also be importing maps to provide the player a real world mapping to a chosen path. They will also manage the creation and maintenance of player profiles. A game session's parameters determine the level a challenge a player will face during the game. Maps dictate the course they will be pedalling on which also effects physical exercise difficulty. Player profiles keeps data relative to the specific player playing during a session.

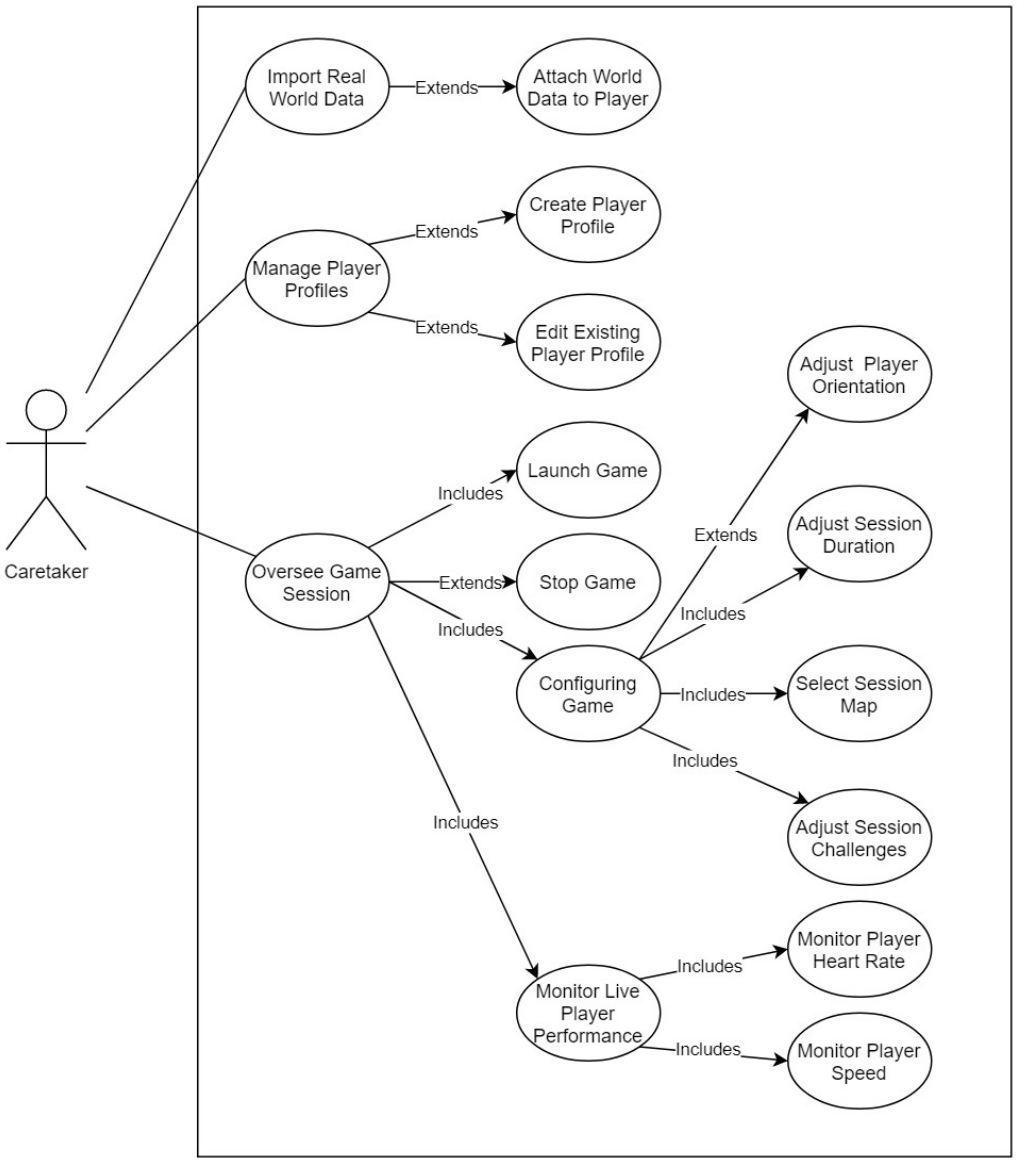


Figure 8.4: Caretaker Use Case Diagram

Caretaker Use Case Table

UC#	Title
C1	Launch Game
C2	Stop Game
C3	Adjust Session Duration
C4	Adjust Session Challenges
C5	Import Real World Data
C6	Select Session Map
C7	Monitor Player Performance
C8	Monitor Player Heart Rate
C9	Monitor Player Speed
C10	Create Player Profile
C11	Edit Player Profile
C12	Adjust Player's Virtual Orientation

Table 8.7: Summary product use case table for caretaker actor.

8.5 Functional Requirements

The functional requirements covered in this chapter will focus on requirements of Cyclescapes that have an impact on the actual game's mechanics/challenges and how the player interacts with them. This includes the VR aspects of the game as they have a non trivial impact on the player experience.

8.5.1 Hardware

FR-HI-1

Related Use Cases: P1, P2, C7

Description: The system must be able to receive data originating from the Ant+ bike trainer device.

Rationale: The game must have pedalling as its form of seated physical activity.

Fit Criterion: When the system and the bike trainer are connected data is received corresponding to the interactions with the trainer.

FR-HI-2

Related Use Cases: P3, C7

Description: The system must be able to receive data originating from the Ant+ heart rate monitoring device.

Rationale: For patient safety it is required to be able to assess the patient's heart rate.

Fit Criterion: When the system and the heart rate monitor are connected data is received corresponding to the interactions with the heart rate monitor.

FR-HI-3

Related Use Cases: P1

Description: The system shall map forward pedalling intensity in real life to a positive velocity in the game.

Rationale: Pedalling in this way maps to real life biking thus better allowing a patient to answer the question of being able to bike between to different real world locations.

Fit Criterion: When a player pedals on the bike trainer in the forward direction, the in game speed should map to the intensity of the pedalling.

FR-HI-4

Related Use Cases: P2

Description: The system shall map zero or negative pedalling on the bike trainer to a negative acceleration.

Rationale: To better map the real world mechanics of riding a bike.

Fit Criterion: When a player stops pedalling on the trainer their in game speed should be reduced.

FR-HI-5

Related Use Cases: P1, C6

Description: The system should be able to adjust and produce resistance of the trainer.

Rationale: Being able to produce resistance for the player is required for mapping real world data into the game world in such a way that it can be interacted with.

Fit Criterion: When the trainer is commanded to increase or decrease its resistance, the difficulty of pedalling on the trainer should adjust accordingly.

8.5.2 Virtual Reality

FR-VR-1

Related Use Cases: P4

Description: The system should be able to interpret and map the movement and orientation of the player's head.

Rationale: If the player's position is not tracked well within VR, this can cause motion sickness in the player.

Fit Criterion: The players virtual position and orientation adjust relative to their real world movements while wearing the VR head mounted display with less than a millisecond of delay.

FR-VR-2

Related Use Cases: C12

Description: The system should allow for re-orientating the player's orientation relative to the virtual world.

Rationale: To account for the required portability of the game and how it can effect the player's origin in the game world.

Fit Criterion: The players virtual position and orientation adjust relative to their real world movements while wearing the VR head mounted display with less than a millisecond of delay.

8.5.3 Gameplay

FR-GP-1

Related Use Cases: P6

Description: The system should be able to generate challenges for the player to complete.

Rationale: Challenges are the main way for Cyclescapes to encourage physical activity of the player.

Fit Criterion: Challenges are created in the game world for the player during a Cyclescapes session.

FR-GP-2

Related Use Cases: P5, P6

Description: The system should notify the player when a challenge has been generated in the world.

Rationale: In order for the player to attempt a challenge they must have knowledge of its existence in the game world.

Fit Criterion: A player is able to know a game challenge has appeared in the game world.

FR-GP-3

Related Use Cases: P7

Description: The game must be able to model and track the players performance relative to the session and challenges presented.

Rationale: The game needs a means to track player actions in the game that reflect the player's ability to play Cyclescapes.

Fit Criterion: The metrics used to track the players performance changes in a predictable manner relative to player actions.

FR-GP-4

Related Use Cases: P8, C6

Description: The system shall be able to generate a path for use in the core game loop with the use of real world data.

Rationale: A project mandate by the pediatric researchers requires Cyclescapes to use real world data in the cycling game.

Fit Criterion: A path is created that is usable in the game that reflects a real world route and simulate the effort required to bike along the designated route.

FR-GP-5

Related Use Cases: P8

Description: The system will be able to track a players position on a course when playing the game.

Rationale: Player position is important for determining if a player has completed pedalling on a specific path.

Fit Criterion: The players position changes relative to player movement in the real world.

FR-GP-6

Related Use Cases: P9

Description: The system shall provide information to the player about their performance.

Rationale: To help motivate the player and provide feedback with respect to player actions.

Fit Criterion: During a session of Cyclescapes the player is able to monitor their current score.

FR-GP-7

Related Use Cases: P7, P8

Description: The system shall acknowledge when a player completes a challenge within the game.

Rationale: To monitor player performance the system needs to know when certain player actions are done.

Fit Criterion: Upon the completion of certain in game actions, the player's model of their performance changes accordingly.

FR-GP-8

Related Use Cases: C4

Description: The system shall allow the enabling and disabling of specific game challenges.

Rationale: To allow the game to be adjusted for player needs and desired play and exercise level.

Fit Criterion: The enabled status of a challenge is saved correctly and reflected during the duration of a Cyclescapes session.

FR-GP-9

Related Use Cases: C3

Description: A caretaker shall be able to adjust the duration of a cycling session in Cyclescapes.

Rationale: To adapt the games endurance testing properties to the fitness level of the player.

Fit Criterion: The game ends after the specified time has elapsed.

FR-GP-10

Related Use Cases: P10, C1

Description: The system shall notify the player when the game enters and exits the play state.

Rationale: For a smoother player experience, the player should know when is appropriate to exercise/play.

Fit Criterion: When the game starts and or ends, the player should be notified of the change in game state.

FR-GP-11

Related Use Cases: P6, C4

Description: The system shall use the players performance to dynamically adjust to their physical ability level during a play session.

Rationale: The goal of this thesis is to assess how to adjust challenges to better motivate exertion in players.

Fit Criterion: Not applicable as this is what is being explored.

FR-GP-12

Related Use Cases: C1

Description: The game shall allow caretakers initiate a configured Cyclescapes play session.

Rationale: The game must be started in order to be played.

Fit Criterion: The caretaker has a method or action to initiate game. Doing so will put the player into the game in progress state.

FR-GP-13

Related Use Cases: C2

Description: The game shall allow caretakers to end the session at will.

Rationale: For the safety of the player, the caretaker must of executive powers to control when the game is being played.

Fit Criterion: During a Cyclescapes session the caretaker is able to force the game out of the in game state.

FR-GP-14

Related Use Cases: P6, P8, C7, C8, C9

Description: The game shall adjust the games difficulty should the exercise infringe on the player's safety

Rationale: A priority for stakeholders involved is the health and safety of the patient players.

Fit Criterion: The game is able to track when the player's heart rate reaches or passes a specified ceiling.

8.5.4 Monitoring

FR-M-1

Related Use Cases: C7, C9

Description: The system shall be able to track the player's current performance in the game.

Rationale: To provide the caretaker information regarding the player's current session.

Fit Criterion: The caretaker is able to see the player's modelled score, location and other metrics associated with the player's game performance (eg. distance travelled).

FR-M-2

Related Use Cases: C8

Description: The system shall be able to track the players heart rate during a Cyclescapes pedalling session.

Rationale: The player's heart rate important for understanding their level of exertion as well as for monitoring player safety.

Fit Criterion: The player's heart rate is viewable while the player is playing the game.

8.5.5 Data

FR-D-1

Related Use Cases: C3, C4, C6

Description: The system is able transfer session parameters between system states.

Rationale: The information must be accurately transferred from game configuration into the actual gameplay such that the player's expectation is met.

Fit Criterion: Configured session parameters are successfully preserved between system states for level construction.

FR-D-2

Related Use Cases: C5, C10

Description: The system is able save data for future reuse.

Rationale: The game is meant to played over multiple sessions. Imported data or previous data should be accessible for future use.

Fit Criterion: Data written by the system is preserved when accessed again.

FR-D-3

Related Use Cases: C11

Description: The system shall be able to edit aspects of recorded player data after data creation.

Rationale: Allows users to correct mistakes or alter certain records based on real world changes. For the purposes of this thesis some aspects of the players recorded physical fitness may change as they play the game more such as a heart rate ceiling.

Fit Criterion: Data from external geographic data files can be read into the system in a state which is usable.

FR-D-4

Related Use Cases: C5

Description: The system shall be able to read geographic data regarding real world location.

Rationale: Real world data is required as part of what is required by the hospital researchers.

Fit Criterion: Data from external geographic data files can be read into the system in a state which is usable.

FR-D-5

Related Use Cases: C5

Description: The system shall transform real world geographic data into a usable form for level construction.

Rationale: Geographic data must play a role in the exercise of the game.

Fit Criterion: A path is created within the game that reflects the corresponding geographic data used.

8.6 Non-Functional/Usability Requirements

The focus of the non functional requirements will be like that of the functional requirements. Aspects of Cyclescapes that impact the player's experience as they relate to the actual game and its mechanics. The player experience conveyed by Cyclescape's non functional requirements will have a significant impact on how well it is received by the player.

8.6.1 Look and Feel

NFR-LF-1

Related Use Cases: P1, P2, P6, P8

Description: The game should not feel like an exercise game but a game with its focus on pedalling as a means of control.

Rationale: The game must be enjoyable and not feel like work to better motivate player engagement with the exercise.

Fit Criterion: 90% of players during user testing respond positively to playing Cyclescapes.

NFR-LF-2

Related Use Cases: C3, C4, C6

Description: The game must have a means of encouraging replay.

Rationale: The patients undergoing treatment who are our target audience must be engaged with the game over multiple sessions.

Fit Criterion: 80% of players still respond to Cyclescapes positively after 3 or more repeat play sessions.

NFR-LF-3

Related Use Cases: C5, C6

Description: The paths generated by the game must look continuous.

Rationale: This should make the virtual environment feel bigger and unified.

Fit Criterion: Players playing the game feel like the path they are pedalling on is continuous.

NFR-LF-4

Related Use Cases: P1, P2, P4

Description: The controls and interaction methods used by the player should feel responsive.

Rationale: To avoid motion sickness in VR and to provide the player a better sense of presence in the virtual world.

Fit Criterion: Inputs by the player should provide feedback within less than 0.5 seconds of input.

NFR-LF-5

Related Use Cases: P6, P9, P10, C1, C2

Description: Information communicated to the player by the game should interact with both visual and auditory senses.

Rationale: Redundancy in information will make it less likely for the player to miss important notification from the game such as objectives and changes in game state.

Fit Criterion: Not applicable as this may not be the best approach depending on the information required by the player.

NFR-LF-6

Related Use Cases: P4

Description: The game shall minimize the factors contributing to potential motion sickness

Rationale: Since Cyclescapes is exclusive to VR to maintain engagement as well as exertion the game must minimize the chances of the player getting motion sick during play.

Fit Criterion: 80% of players playing Cyclescapes during user testing report little to no motion sickness.

8.6.2 Usability

NFR-U-1

Related Use Cases: P9, P10

Description: All visual interfaces for the player in VR should be of a size that is easily readable.

Rationale: If the visual messages are not readable they are not usable by the player.

Fit Criterion: All text in the virtual world is clear and can be read by 90% of all players.

NFR-U-2

Related Use Cases: P6

Description: Players should be able to focus on a given challenge and not be overloaded with tasks to complete.

Rationale: With reference to gameflow, the game wants to encourage focus and minimize distractions. Having more challenges in the environment will potentially split a player's concentration.

Fit Criterion: When a player is completing a challenge no other challenges appear.

NFR-U-3

Related Use Cases: P4

Description: All displays made to the player should not unbalance or otherwise put the player in a dangerous position such that there is a significant chance for being injured.

Rationale: The player should be safe playing the game.

Fit Criterion: All players report positively with respect to feeling balanced during a Cyclescapes session during the user testing trials.

Chapter 9

System Architecture

From chapter 8, we know there are three core aspects that make up Cyclescapes. The caretaker user interface that allows the caretaker to monitor the player during a gameplay session and configure the game with challenge details and geographic data. There is the game aspect that encapsulates challenges and actions that make up the exergame and thus the exercise invoked by Cyclescapes. Then there is the data component that reads and writes the corresponding data for use within the system as a whole. Fortunately many aspects of the development of Cyclescapes have been simplified due to the use of the Unity3D game engine. Many of the fundamentals that make the base of a game such as the physics, graphic rendering and basic sound will come out of the box with the Unity3D game engine. This allows us to focus Cyclescapes's architecture on supporting the requirements listed in chapter 8.

There will be a difference between the logical architecture documented in this chapter of Cyclescapes versus the actual implementation structure. This difference is mainly attributed to the fact that the Unity 3D game engine encourages a component based implementation.

9.1 System Overview

Cyclescapes as a software application is asymmetrically built for two different users. For this reason we have decided to split Cyclescapes into two core systems. The caretaker system responsible for handling caretaker input and fulfilling the use cases found on table 8.7. The game/player system responsible for the actual moment to moment gameplay and player experience, see table 8.6. The third system is the database system of Cyclescapes - it is responsible for the writing and reading of any information for long term use. Figure 9.3 depicts the association between the systems that make up Cyclescapes and their interactions with the end users.

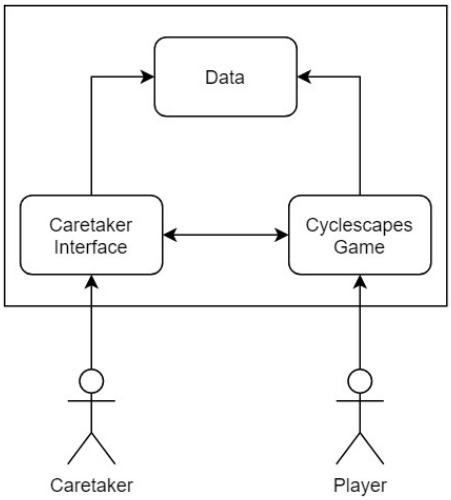


Figure 9.3: Cyclescapes System Relationships

9.2 Caretaker

The focus of the caretaker system is to facilitate the interactions required by the caretakers. To group the caretaker's interactions and responsibilities by use cases they are as follows, a more detailed analysis of the uses cases and the derived requirements can be found in chapter 8.

- **Manage Player Profiles:** C10, C11
- **Configure Play Sessions:** C1, C2, C3, C4, C6, C12
- **Import Geographic Data:** C5, C6
- **Monitor Player:** C7, C8, C9

All responsibilities of the caretaker system require a user interface on the main computer, not in VR. Due to this reason, we will focus solely on the subsystems that make up the caretaker system and ignoring how they interact externally. The base structure for the ideal structure of the caretaker system is the presentation abstraction control (PAC) architectural pattern. The organization logic behind PAC architecture is similar to the organization logic behind component based architecture. This will allow more direct translation between the logical organization of Cyclescapes to actual implementation in our code base. Following PAC architecture we can divide each grouping of caretaker interactions with Cyclescapes as its own subsystem. Figure 9.4 depicts the high level organization of the Caretaker subsystems in relation to the rest of Cyclescapes.

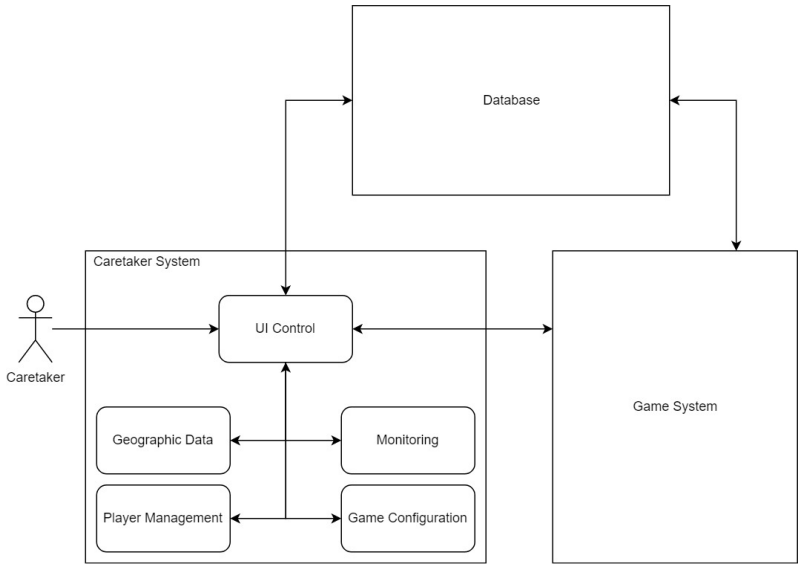


Figure 9.4: Caretaker System Subsystems

Using PAC architecture as inspiration, the UI control component is responsible for managing the caretaker user interface hierarchy and the the flow of data between the subsystems in the Caretaker system and the rest of Cyclescapes. It is the state machine that controls which presentations are shown to the caretaker and allows the caretaker to isolate their interactions with each subsystem/module.

9.2.1 Geographic Data

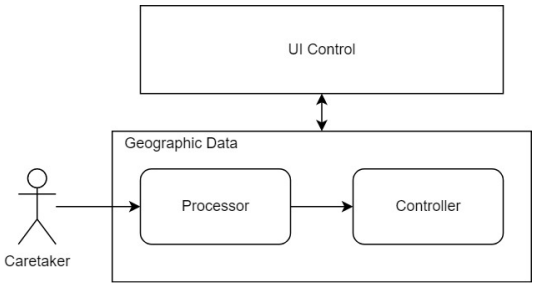


Figure 9.5: Caretaker Geographic Import Subsystem

Processor

Requirement: FR-D-5
This module is responsible for acquiring relevant data and information for the transformation of real world data into a game usable data structure. The data

structure should accurately reflect the desired input data set provided by the caretaker as that is critical for the difficulty adjustment for the player.

Controller

Requirement: FR-D-2
The controller will send the processed data to the rest of the system through the hierarchy of agents to be saved in the database. Maps must be saved for future reuse for players wanting to replay certain maps. A key goal for the project is to allow players the practice of certain bike routes over and over again.

9.2.2 Player Management

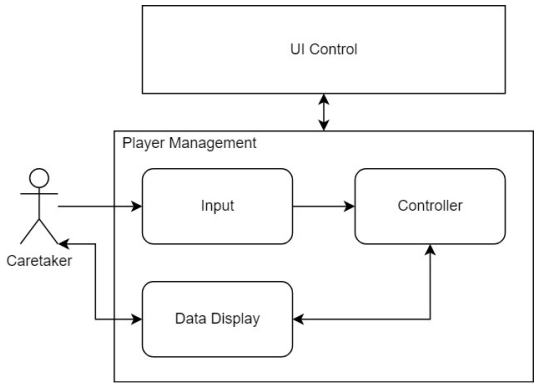


Figure 9.6: Caretaker Player Management Subsystem

Input

Requirements: FR-D-2, FR-D-3
This module is responsible for acquiring and error checking input to the system for the player before the data is written. This includes during the use case of player profile creation and post creation edits.

Data Display

Requirement: FR-D-3
The module is responsible for accurately displaying data regarding the player profile data such that the caretaker understands what aspects of the profile require adjustment.

Controller

Requirements: FR-D-2
This module is responsible for transferring input data obtained in this subsystem up the caretaker system hierarchy to be saved for future use.

9.2.3 Monitoring

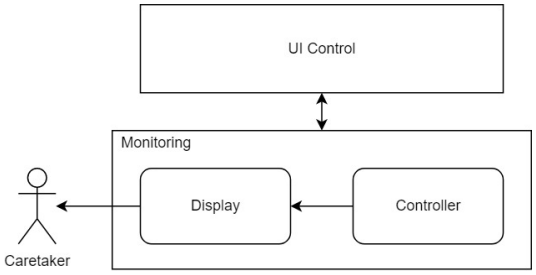


Figure 9.7: Caretaker Player Monitoring Subsystem

Display

Requirements: FR-M-1, FR-M-2
This module is responsible for display information to the caretaker user regarding the players performance metrics and bio metrics such as heart rate.

Control

Requirement: FR-D-2
This module controls the flow of data between the rest of Cyclescapes and the display module.

9.2.4 Game Configuration

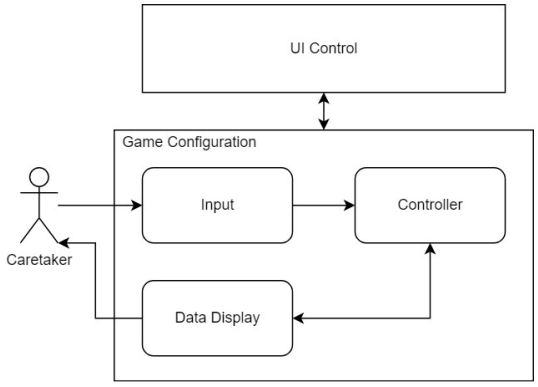


Figure 9.8: Caretaker Game Configuration Subsystem

Input

Requirements: FR-GP-8, FR-GP-9, FR-GP-14,
This module is responsible for interpreting input from the caretaker user and then passing it on to the rest of the subsystem for in-game use.

Data Display

Requirements: FR-GP-8, FR-GP-9, FR-GP-14,
This module is responsible for correctly displaying the options available to the caretaker user for possible configuration settings for the game session. This will allow caretaker users to precisely set configuration settings to the players required configuration.

Controller

Requirement: FR-D-1
This module is responsible for communicating data set within this subsystem to the rest of the game. It also communicates available configuration settings to the data display module.

9.3 Game

The organization of the game aspect of Cyclescapes is based off of Unity3D's encouraged design pattern - component based architecture. It also takes inspiration from simple control systems this helps meet the requirement *FR-GP-14*. Figure 9.9 depicts the modules in regards to the data flow of the game system

for Cyclescapes and how it flows into the rest of the systems. The modules are split based on use case as they better encompass what is to be achieved.

- **Player Input:** P1, P2, P3, P4
- **Game Controller:** P10
- **Challenge Manager:** P5
- **Challenge:** P6
- **Game State Monitor:** P7, P9
- **Level Generator:** P8

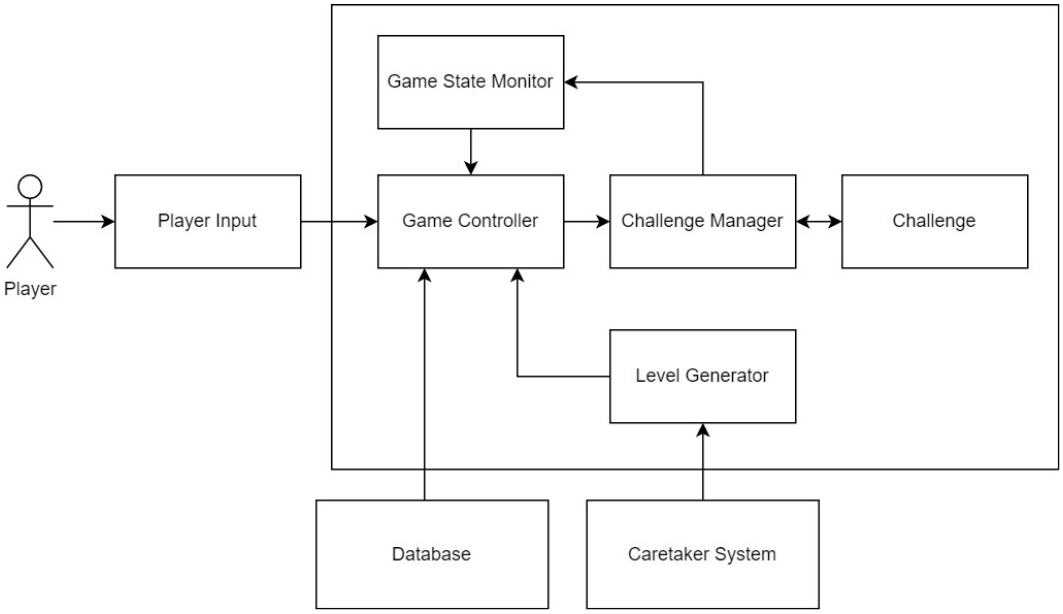


Figure 9.9: Player/Game System Subsystems

In the architecture depicted in figure 9.9 we are assuming that each component within the structure will control its own visual presentation. This allows our design to focus more on the aspects of the game that require code and aspects of the project that will be taken care of by the Unity game engine.

9.3.1 Player Input

Requirements: FR-HI-3, FR-HI-4, FR-HI-5, FR-VR-1
This module is responsible for interpreting player input from specialized hardware such as the VR head mounted display and cycling trainer. After processing the input signals created by the player the module will send it forward

and into the rest of the game. This module is largely covered in the interfaces in Unity3D that will process the provided stream of data and signals.

9.3.2 Level Generator

Requirement: FR-GP-4
This module takes in real world geographic data and parameters set by the caretaker during game configuration and translates them into a base world. It is required to generate the world the player will be playing in throughout the duration of a play session.

9.3.3 Game Controller

Requirement: FR-GP-14
The game controller module as in the name acts as the controller for the game. It takes in information about the game a dictates how the game should be altered to best match the desired physical difficulty for the player. In context with this thesis, it is a core part of the implementation that will need to be evaluated.

9.3.4 Challenge Manager

Requirement: FR-GP-1
This module acts as an interface for the game controller for selecting challenges for the player to generate in the game world. This module is intended to future proof the game such that additional unique physical challenges can be easily added to the game with little to no change to other modules within the game.

9.3.5 Challenge

Requirements: FR-GP-2, FR-GP-7
A challenge component defines a specific set of rules within the game. In the architecture diagram in figure 9.9, the challenge component is kept singular and abstract as the actual design of the challenge will be subject to change after user testing. The challenge module will also follow Unity's component based design philosophy. It should contain all relevant data structures and code for defining the challenge. This includes visual presentation, rules and potential interaction methods.

9.3.6 Game State Monitor

Requirements: FR-M-1, FR-M-2
The Game State Monitor module is responsible for monitoring all relevant

player statistics during game time. Similar to the many a computer with external facing sensors, the monitoring module will obtain data during the players gameplay session and provide that data to the game controller. This module should be made extensible to what is recorded as more feedback from the actual test audience might request for different statistics to be captured.

9.4 Data

The data part of Cyclescapes encapsulates the storage and communication of data between the two core systems of Cyclescapes. The main responsibilities of the Data component of Cyclescapes is the management of player profile data, the management of play session data and the management/storage of the real world data used during level generation. Figure 9.10 depicts the system and subsystem relationships and organization.

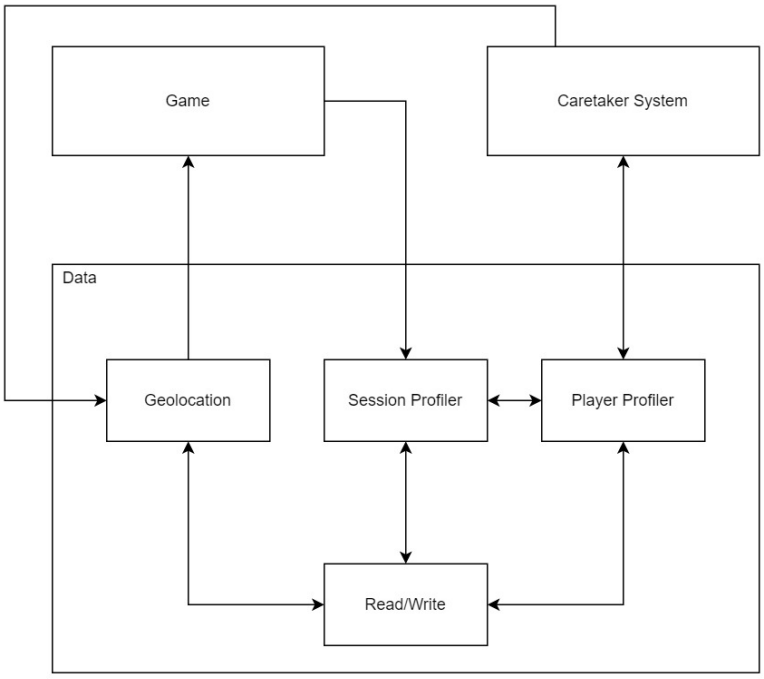


Figure 9.10: Data System Subsystems

9.4.1 Geolocation

Requirements: FR-D-4, FR-D-5
This module is responsible for creating the data set that represents the real world path intended for player use during a session of Cyclescapes. This module will handle to importing of new geographic and the restructuring of

the geographic data for convenient future reuse. We are using google map's api for completing data sets required in the game. This adds a cost factor to consider when deciding how we should approach the creation of data sets.

9.4.2 Player Profiler

Requirement: FR-D-3
This module is responsible for creating and structuring data related to a player's profile. This will include an interface for the cartaker systems to interact with to submitting data from any forms that may take in caretaker user input.

9.4.3 Session Profiler

Requirement: FR-D-1
This module is responsible for creating and structuring data related to a played session of Cyclescapes. This includes recording and structuring meta data of the game session that describes a player's performance. The module will also relay this information back to the caretaker system for in system analysis after a given Cyclescapes session.

9.4.4 Read/Write

Requirement: FR-D-2
This module is responsible for encoding data of the Cyclescapes system such that it can be reused/accessed in the future.

Chapter 10

Cyclescapes Design

For the purposes of scoping for this thesis, the design covered in this chapter will provide an overview of the game side of Cyclescapes. The other use of presenting and storing the players data will not be covered in the section. We will focus on all items and design choices made in service of encouraging player exertion.

The purpose with respect to the game side of Cyclescapes is to achieve patient goals. The primary goals for the patient/player being a distraction from their on going treatment and an outlet for physical activity. The secondary goal for the player or guardians of the player is for physical fitness training and validation. Players and their guardians wished to assess the player's physical fitness capabilities and potentially improve on them by means of more consistent physical exercise. As mentioned before we will be ignoring the caretaker/researcher side of the system, the data collection and analysis tool.

10.1 Design Goals

The game aims to achieve the following goals. They are ordered by priority from most important to least important with respect to what needs to be done and what is nice to have. We have divided the goals into primary goals and secondary goals. Primary goals are the main objectives for Cyclescapes and the secondary goals are the supporting objectives meant to aid in the achievement of the primary goals.

10.1.1 Primary Goals

The intent behind the primary goals are to help the player achieve flow, more specifically dual flow - the balance of the game's physical and gaming challenge as described in section 4.2. The primary goals are also set to facilitate the stakeholder requirements as described in chapter 8.

1. The game must motivate the player to exert and perform physical exercise.
2. Pedalling must be the primary input/interaction between the player and the game.
3. The game must keep the player engaged through multiple sessions of play.
4. Any player action done in the game should have immediate feedback displaying a system reaction.
5. The games mechanics should be intuitive for the player to interpret and learn.
6. The game mechanics must be adjustable to a degree to match the player's preferences.
7. The difficulty of the game must adjustable to match the player's displayed abilities with respect to gameplay challenges and physical fitness.
8. The game must not incite aggressive behaviour in the player.
9. Adjustments made outside of a game session should be intuitive.

10.1.2 Secondary Goals

Secondary goals are intended to facilitate the completion of primary goals.

1. The game should enable players to focus on the challenges presented to them.
2. The game should help the player track in-game goals.

10.2 Cyclescapes Description

10.2.1 Player Oriented

The core design of the game is based on mobile games such as *Temple Run* and *Subway Surfer*. To avoid simulator/motion sickness the player will be pedalling on a single path with no lateral/strafing. The player will only have control of the speed at which they are moving.

The game implemented is an on-rails collection game. The player will be riding on a vehicle along a predetermined path. To move the vehicle the players must pedal on the bicycle trainer. The speed they will be moving at in

the game is relative to their real life pedalling speed. The path in Cyclescapes will be created based on an actual map provided by the user. Difficulty of the path will be modified based on the actual terrain the path is created from. The difficulty for the path refers only to physical difficulty of the exercise. Along the path the player will collect gems by completing different challenges. The gems will contribute to the player's final score. All challenges are designed to maintain the player's forward momentum and therefore will appear in front of the player. There are three main challenges as mentioned in section 7.2.1. There are aspects of the difficulty of each challenge that are adjusted based on a pre-selected intensity by the player. There are aspects of the difficulty for the 2 special gems that adjust dynamically with the player. The game ends when either the set time limit has run its course or if the player completes the distance of the path they have chosen. The final score the player achieved is based on the number of gems collected on their journey. The way the gems are obtained makes the gem count a model for the quantity of exertion achieved.

10.2.2 Caretaker Oriented

From the perspective of the game, the amount of caretaker interaction is minimal. The caretaker is responsible for the initial configuration of a given Cyclescapes session. This includes determining which challenges are present during the game, setting the duration of the session, the input of geolocation data and the selection of geographic data to be used at level generation.

During a live session of Cyclescapes, the caretaker will have the ability to monitor the player's in game performance as well as manually adjust the difficulty of the path should the physical difficulty of pedalling become to difficult for the player. This use would be rare as the goal of using geographic data is still to mimic the difficulty of biking on the selected route.

10.3 Input Design

10.3.1 Inputs

The player will be playing the game in first person as it is the most intuitive means of inserting the player in the virtual world through the use of VR. The player will be able to adjust their speed based on their physical exertion on the cycling trainer. The faster they pedal on the trainer the faster their in-game speed. The player's momentum will also be kept when they stop pedalling. This interaction is meant to mimic the reality of biking and physics of the real world to create a more immersive experience while also creating a more immersive experience.

10.4 Challenge Design

The challenges needed in Cyclescapes are all built and designed around the 1 dimensional input we obtain from the player. The challenges/objectives in the current iteration of Cyclescapes revolve around the collection of objects. This adds a gamification element on top of the mundane cycling of a bike path while also meeting the requirements of a structured predetermined cycling routine. Each challenge is meant to engage the player in a different way of using their pedalling effort. In hopes to allow the player to focus on each challenge individually, the challenges are mutually exclusive. By having different challenges going at separate times, the hope is to provide the player variety when playing Cyclescapes as well as time to focus on each challenge, fully engaging with them and hopefully output more physical effort during their play session.

All explicit challenges within Cyclescapes contribute to a score meant to abstract and model the physical effort a player outputs in conjunction with their relative success at completing in game challenges. This is done to ensure that the game still functions as a game rather than just a tool for measuring physical ability. This means that a player simply pedalling for as fast and as hard as the can might get a lower score than the player following in game prompts for the challenges outlined in this section. Each explicit challenge will have a different appearance to allow the players to quickly understand what challenge is active during the game.

Non explicit challenges will not directly contribute to the score. For Cyclescapes in its current iteration this includes the recreated slope and trainer resistance from geographic data.

A core philosophy we arrived at when deciding on a design for the challenges considering the target demographic and purpose of the project is the removal of explicit punishment. The game will allow players to perform to their ability and should not be punished explicitly for under performing on any given day. This is to accommodate and motivate players with lower physical fitness abilities and the general player who is not having a good day. As such, all challenges will only ever add to the player's score and never take away the achievements they have earned.

10.4.1 Base

The base challenge, also known during the development of Cyclescapes as the base gem is the lowest/easiest form of challenge. If it is active during a session of Cyclescapes it is meant to test a player's base endurance. This challenge does not dynamically adjust to the players performance during a live session but has its difficulty set at the session configuration step of launching the game. This challenge populates the generated level with green gems along the course

the player is travelling. Acting like distance markers, as the player pedals through the game world they will naturally collect the base gem - assuming this challenge is enabled at session configuration.

Adjusting the desired physical activity intensity level changes the distance at which the base gems are generated in the game world. For example, a higher desired intensity will cause the gems to be added with more distance between each individual base gem. This will require players to pedal further to achieve the same score as a lower difficulty and thus

The base gem is intended to set the precedent of reward with the collection of gems, provide constant stimulus to the player for their efforts and give the player a quantifiable value to match their physical effort and pedalling.

10.4.2 Burst

The burst challenge is designed to incite an elevated level of physical exertion within the player. The burst gem challenge is generated in the game world along the path the player is biking on randomly. When the gem is created in the game world it starts at half of what would be its top speed, quickly accelerating to the specified top speed. The purpose of acceleration is to give time for the player to register the new challenge in their mind and react to it accordingly. As a challenge, it rewards the player significantly more , contributing more towards the players score should the challenge be completed successfully. Similar to the base gem challenge, the burst challenge will only ever appear in front of the player. This is to reduce the amount of upper body motion in VR in the form of dramatic turns of the torso and encouraging the player to face forward, in a safe position.

There are two forms of adaptation the burst gem/challenge uses to adjust to player performance. One form of adjustments for the burst gem comes in the form of session configuration. During session configuration, the caretaker is able to set the games target physical intensity level for the player. Due to lack of target audience player data and testing the parameters adjusted based on the physical intensity configuration require further refinement. The aspects of the challenge that are changed based on the physical intensity setting is the frequency at which this challenge appears for the player.

The second form of adaptation the burst challenge uses dynamic adjustments to monitored player performance metrics. This challenge tracks the players speed, number of consecutive successes and failures as parameters for adjusting the challenge difficulty. What the challenge adjusts is the bounds in which the top speed of the gem created accelerates to.

The speed of the gem is calculated based off of the player's averaged speed over the past specified time period. In Cyclescapes current iteration this time

window is 10 seconds but this will be furthered refined with actual user testing with the target audience. By adjusting the speed of the challenge, and therefore the speed a player must achieve to complete the challenge successfully based on the actual player's speed it will provide challenge to players pedalling at any speed. Requiring players to pedal just a little bit faster to accomplish the challenge and hopefully motivating the player to increase their physical intensity for a short burst of time.

The bounds of which the gems speed is decided change based on the successes and failures of the player to complete the challenge. In Cyclescapes current iteration, consecutive successes will lead to the speed window for a burst gem to increment up, increasing the potential required speed of future burst gem challenges. Should the player fail to obtain a gem after successful completions of the challenge The speed window for the burst gem challenge will be reduced to its starting values. If there has been no changes made on the challenge's top speed and the player is still unable to collect the burst gem, the speed window for the burst gem will decrease, with each successful collection of a burst gem slowly increasing the speed window. Adjusting the potential speed for the challenge in this way allows the challenge to accommodate high achieving players by gradually increasing the physical effort required to successfully complete the challenge. Understandably, collecting a burst gem may physically exhaust the player and the flooring of the speed window should accommodate for this. For player failed attempts at this challenge we want the challenge to find the optimal speed bounds for the player such that they are still motivated to exercise and not demoralized by being unable to complete the challenge throughout the entire session. It is important that this challenge adds to the exercise of the player not making them stop pedalling to either exhaustion or lack of motivation.

10.4.3 Duration

The duration gem is designed to incite elevated levels of exertion in the player for as the name describes an extended period of time. Similar to the burst gem, a major reason for its existence is to add variety to the challenges present in Cyclescapes. The duration challenge gem moves slightly faster than the player and rewards the player for continuing the elevated pace. This game challenge is inspired by the zombie chase mechanic in *Zombies, Run!*, a game we examined in further detail in chapter 6. The difference in approach for our challenge in Cyclescapes is changing the motivation factor to being a reward instead of a punishment. The longer a player is able to pedal along within range of the duration gem challenge the more the challenge contributes to their score. Keeping our Cyclescapes target audience in mind we need to be careful with how we choose to encourage the players to engage with the challenge. Due

to our target audience being mainly sedentary and physically unfit because of factors out of their control we think that a positive reward based motivation based system will encourage the players to move more. If a player goes outside the connection range of the challenge, either by slowing down or pedalling too quickly the challenge is concluded. The design of the challenge encourages the player to pace their pedalling efforts or set duration of time.

For the duration gem challenges a player's endurance for elevated physical activity. Following similar adjustment methods as described for the burst gem challenge, the duration gem challenge can be manually adjusted at session configuration and has certain parameters that change based on player performance metrics.

The manual configuration of the duration challenge determines the starting length of time a player must pedal beside a duration gem to collect the full contribution to their score. The more intense the target physical exercise to be achieved the longer a player has to pedal along the challenge gem and therefore the more potential points can be added to the player's score. The consequence for being unable to go for the full duration of a duration gem is the loss of potential score gain.

The automatic adjustments made for the duration gem are the speed at which the gem for the challenge moves at and the length of time available for the player to connect with duration challenge gem and score. Similar to the burst gem challenge, the speed of the duration gem is based on the speed a player achieves averaged out over a fixed period of time. The speed of a duration challenge does not change over the duration of a Cyclescapes session. Therefore the optimal relative speed needs to be refned through further user testing.

The length of available time a player can connect with the duration challenge adjusts based on the players full connections a player is able to achieve. The success of this challenge is more complex than the burst gem challenge, with only a success or fail state. For the duration gem, we have grouped the success of the player into three distinct groups. A full collection is when the player is able to pedal along side the challenge for the full duration of the challenge. A partial connection is when a player is only able to pedal with the gem for a part of the challenge duration. A missed connection means the player was unable to connect with the gem. When a player is successful the game will provide the player more opportunities within this challenge to further increase their score. A partial connection would cause the system to reduce the potential available for collecting. This is done such that a player is not over worked by the game's challenge for less physical adept players and to encourage pacing in those that have more physical fitness. A missed connection causes the duration of the duration challenge to be reset to the base value. This decision assumes that a player that is unable to connect with the

gem is low on energy and intends to reduce over working the player due to the game's mechanics.

Similar to the base gem challenge and the burst gem challenge, the duration gem challenge will only appear in front of the player to reduce the amount of upper body motion in VR in the form of dramatic turns of the torso and encouraging the player to face forward, in a safe position. The duration challenge contributes to the score based on the amount of time a player is able to pedal beside the gem after connecting.

10.4.4 Level Generation

Level generation discussed in this section refers to the translation of real world geographic data to an in game course for player use. With regards to the games challenge the map does have an effect on the difficulty of the game. Following the requirements and request provided by our client, the pediatric researchers and as described in *FR-GP-4* the game must be able to model the desired real world route in the game. Bike routes with more inclines or more severe inclines will naturally be more difficult to pedal on as the game will translate that incline into resistance on the bike trainer.

Level generation effects the underlying physical exercise difficulty for the entire game. The ability to adjust this difficulty is all manually configured by the caretaker user. The first method to adjust the difficulty of the level is to select a real world route with little to no inclines. The important aspect of the routes we need is the change in elevation and distance. We are choosing to ignore turns and curves there can be certain map inputs that have very sharp turns which may induce motion sickness in the player. With just the elevation and total distance of the bike route we generate a straight level for the player to pedal along where the change in elevation matches what would be found in the real world. The resistance provide the trainer showing the changes in slope of the map is designed to, at its base mimic the slope of the actual terrain. The other option to change pedalling difficulty of level generation is done during a game session, again by the caretaker user. To make the game more accessible and give all players a chance to pedal to completion we provide the caretaker a means of manually adjusting the resistance on the trainer while monitoring the player's performance. This decision is meant to provide the caretaker a means of assisting the player by altering the difficulty of the course. This also includes making the bike route more difficult for players who seek a more difficult physical challenge throughout the game. The main objective for this design choice is to target the more sedentary players that may be struggling on a course and need the assistance to get started with physical exercise.

10.5 Player User Interface

The player user interface will all appear to the player in VR. There is no component on the desktop side of the application that will be intended for use by the player. The current iteration of Cyclescapes focuses on making information provided to the player easy to digest, minimal and intuitive.

The interactions from the hardware is intended to be intuitive. The decision for the game to map the player's pedalling to fit the forward movement of a bike in the game makes the controls of the game intuitive due to the inherent mapping to real life. Therefore any kid with experience pedalling a bike or have seen a bike be used should be able to recognize how they should be interacting with the trainer. As for the VR system, our decision to ignore the VR controllers removes the necessity of explaining/mapping controller inputs. The base orientation and position tracking of the VR head mounted display will map to the physical movements of the player therefore making player's ability to look around in the game world map directly to how the player would look around in the real world. Overall the choice of technology constraining the project offers a lot of out of box intuitive controls for the player.

The player will have a constant display throughout the play duration displaying the score which model's their performance relative to the game. We have decided to remove any reminders of their exercise such as speed, so that Cyclescapes will hopefully feel more like a game where the method of input so happens to be physical. Minimizing the about of data a player needs to process playing this game was also an important factor for this design decision as we want to allow the player to focus on the challenges presented in the game as well as to immerse themselves in the virtual environment that was created.

Challenges in the game as mentioned in section 10.4 will be displayed to the player in 2 ways, following the requirement *NFR-LF-5*. Visually the gem challenges will have distinct colours to represent each. For the current iteration of Cyclescapes, the base challenge is green. The burst challenge gem is red. The duration challenge gem is purple and scaled to be larger. The visual differences of all challenge gems are as seen in figures 10.8.

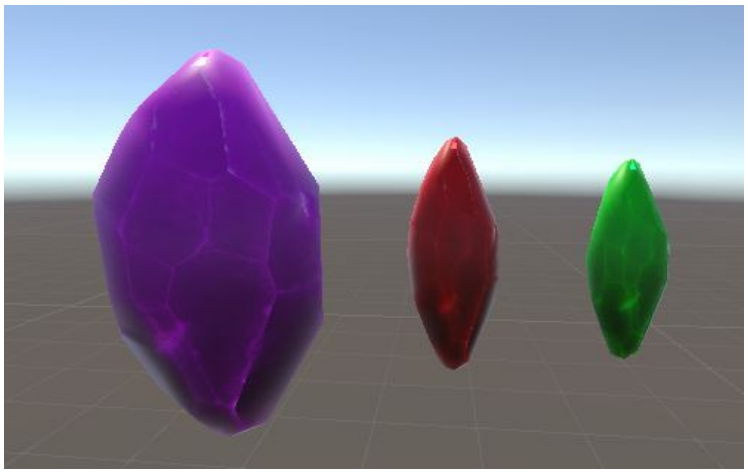


Figure 10.8: Challenge Gems in Cyclescapes.

The audio representation of each challenge are voiced instructions that inform the player of the challenge and how to complete it. This should convey enough information such that the players are able to understand what to do at any given moment with respect to the game and how to improve their score. Completing the challenges within the game also provides auditory feedback. This serves 2 purposes. The first is to clearly convey to the player that they have completed a challenge. The second takes inspiration from games like *Flappy Bird* and slot machines. It is to provide positive motivation. Each challenge completion will sound off with a positive tone. This in hopes of motivating the player to collect more gems, thus improving their score and increasing the amount of exercise accomplished.

10.6 Virtual Environment

The virtual environment we are building focuses on the request by the pediatric hospital of escapism. The hope is the environments employed by the game during level generation make the players feel as if they are in another world.

10.6.1 Visual

Though the visual aesthetic of the game does not have a direct relationship with the research question of this thesis, it is still important for keeping the player engaged with the game. The core visual aesthetic for Cyclescapes is low polygon assets. The choice of low polygon assets supports the idea of another world as it is distinctly different from the real world. Having an artistic style allows us the freedom to create a more cohesive aesthetic but also make it have elements of fantasy, such as the vehicle we are using to represent the player

in game, a magical boat. Figure 10.9 demonstrates the low polygon art style in the trees within the Cyclescapes game. Having a low polygon aesthetic style will still allow for the implementation of more relevant themes such as an urban city landscape while affording us as designers to explore more outlandish ideas, like a cave system or outer space.

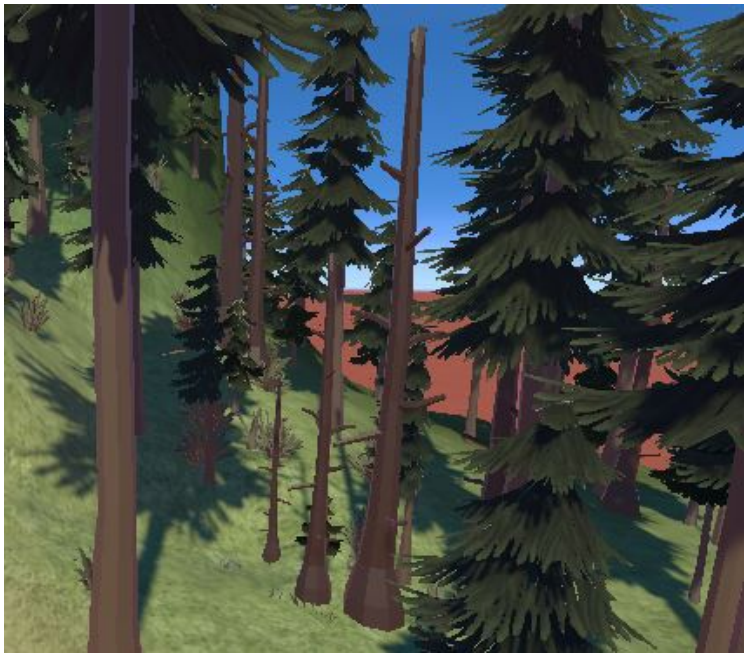


Figure 10.9: Low Polygon art assets making up the forest theme of the current iteration of Cyclescapes

Originally we did explore the idea of more realistic environments like those found on *Google*'s *Street View* but this would be to costly financial and in terms of processing when rendering the game in VR. Optimization is important because a decrease in frame rate for the player while wearing the VR headset can lead to motion sickness as described in chapter 5. The environment generated in the game strings together an assortment of hand crafted tiles of an environment. The tiles join together making a seamless continuous level.

10.6.2 Audio

The purpose of this thesis is not to explore the effects of music and audio prompts on the exercise quality of a player during a play session of an exergame. It is important to understand however that music does have an impact on the player's experience which could have an effect on the exertion of the player. The core use of sound in Cyclescapes is to convey information. Sound

is played when a challenge is complete. An audio based method of feedback reflecting the player's speed is used to convey to the player when they are pedalling faster versus when they are not going as fast. State change will also be reflected in the background music played. A different background music track is played when the player is in the waiting room area, waiting for the game to be configured and launched compared to when the player is in game. The focus on using audio to convey information is based off of requirement *NFR-LF-5*. It also allows us to minimize the information visually displayed to players such as the instructions for completing each gem.

Chapter 11

Proposed User Testing

Due to the current global circumstances during the conduct of the Cyclescapes project and the writing of this thesis we will be unable to conduct user tests with the specified target audience of our implemented version of Cyclescapes. The effectiveness of the mechanics and design employed in Cyclescapes require testing. As a reminder, the research question we are addressing in this thesis;

How can a game that mandates physical exercise be adapted to the physical and gaming abilities of the player such that the player is encouraged to move?

The design of the user tests that would be conducted in this chapter will be designed to determine if the solution we implemented as Cyclescapes is successful in encouraging the player to move.

11.1 Study Overview

The goal of the proposed user study is to analyze and determine the effectiveness of the game mechanics in the current version of Cyclescapes for inciting physical activity in its target audience. To determine the effectiveness we will use the metrics as defined in chapter 7, such as the player's exercise intensity. Combing objective results with subjective feedback, the aim is to determine which mechanics implemented in Cyclescapes motivate the player to move, which hinder the player's exercise and what features could be potentially better suited for the goals of the project. The study should evaluate the effectiveness of adaptation of challenges done respective to the player's preferences and physical ability.

11.1.1 Participants

The demographic for the target audience of Cyclescapes is large. The age range is between the ages of 6 to 17. This is an incredibly large demographic to cover and process information for. For studies involving children and stepping into the realm of pediatrics, consideration must be made for the underlying effect of growth and maturation [14]. For this reason the should be conducted in iterations based on grouping made based on the participant ages. A granular grouping would be to group participants by age. Each iteration of the study would examine one age, such as a study with 6 year old participants and a study with 7 year old participants. Following this age grouping structure, there would be study conducted for each age between 6 to 18. This approach can be impractical when conducting each study as it will be difficult to get the required volume of participants at each age. From discussing things with the pediatric researcher, Dr. Joyce Obeid who we are building Cyclescapes for, in their research age bins is a good approach for grouping participants by age. The age bins approach has 3 general groupings. There is a grouping for younger children filled with the age range of 6-9. The early pubertal kids, ranging from age 10 to 13. The last age bin would be teenagers, ranging from age 14-17 years old. The age bin approach is the suggested approach due to its practicality for finding participants matching the grouping while following a precedent in pediatric studies as discussed with Dr. Obeid.

Another criteria for participant selection should include the physical activity lifestyle of the participant. The lifestyle for the participants should mirror the lifestyle of Cyclescapes target audience. Following the definition provided by the World Health Organization, we should have participants be significantly sedentary. The World Health Organization defines *significantly sedentary* as getting less than 1 hour of physical activity in a day[5]. After meeting the criteria for selection, it may be important to understand more specifically how much physical activity a participant may get in a week. It may also be useful to know if a player has ridden a bike before. The participant's bike riding experience may have an impact on how well they perform and move within Cyclescapes where the primary mode of physical exercise/input is pedalling a bike. Figure 11.3 has questions to understand the participant's physical abilities.

1. How many days in a week are you physically active?
2. Have you ridden a bike before?

Figure 11.3: Pre-Screening Questions: Exercise/Movement

From MacKenzie's textbook, *Human-Computer Interaction*[38] it recommends that quantity of participants for a study follow similar studies in this domain. During our time looking into similar studies the range of participants used in the studies ranged from 8 to 14 [64, 65, 39]. It is important to note that there are also 4 variants of Cyclescapes that may be impacted by the order. To allow for counterbalancing, the use of latin square may be required, thus a multiple of 4 should be used for the number of participants in each study iteration. Constraining the number of participants for practicality a single iteration of the study for each age grouping should have either 8, 12 or 16 participants.

The following characteristics of the player should be noted but does not need to be an explicit criteria for participant selection. The gender of the player may have an effect on the player. Recording gender will allow us to potentially see and analyze any biases, if any are in the design of Cyclescapes towards a specific gender. The amount of video games the participant plays. Figure 11.4 is a list of question to gather relevant gaming experience data on the participant. The level of experience the participant has had with VR. Figure 11.5 is a list of questions to gather relevant VR experience data on the participant.

1. Do you play video games?
2. How many days a week do you play video games?
3. How many hours a day do you play video games?
4. Name up to 5 of your favourite video games?

Figure 11.4: Pre-Screening Questions: Gaming Experience

The questions regarding video gaming experience in figure 11.4 are meant to ascertain the quantity of playtime a participant gets in a given week as well as the type of games played by the participant. Both factors may have an effect on the reception of the current iteration of Cyclescapes.

1. Have you heard of virtual reality?
2. Have you played in virtual reality before?
3. How many hours have you played in virtual reality?
4. If possible name your favourite virtual reality experience?

Figure 11.5: Pre-Screening Questions: VR Experience

The questions regarding VR experience in figure 11.5 are meant to determine the level of prior experience and exposure to VR experiences. VR has a non trivial part for Cyclescapes and it is important to understand if there is an impact caused by the experience level of the participant with respect to VR.

11.1.2 Apparatus

The study will use a computer with requirements equivalent or greater than the parts found on table 8.5. The monitor display used to display the caretaker's side of the system should have no effect and as such will not be defined environmental setting mandated by this study proposal.

For the peripheral devices, those being the VR head mounted display and the cycling trainer the study should be using the same devices used during the development of Cyclescapes, found in figure 8.2. The head that will be is used and tested will be the *HTC Vive Cosmos* as shown in figure 5.5. For the purposes of Cyclescapes the controllers of the *HTC Vive Cosmos* will not be required.

Cyclescapes requires the use of Ant+ communication based devices. The base USB dongle used should be Garmin's Ant+ dongle. The trainer, the game is the *Elite's Suito* indoor bicycle trainer. The heart rate monitor will be the *Polar OH1*.

We mirror the devices used during development to ensure the function of the whole system with respect to the experience that we designed. The most important hardware to match is the *Elit's Suito* indoor bicycle trainer as different indoor trainers come with a different suite of available functions and we can only guarantee the game works with the specified device.

For the software required to conduct the test the latest functioning build of the Cyclescapes game is required. All configurations for conducting the test with Cyclescapes will be available to configure within the system's menus by the experimenter.

11.2 Study Design

There structure of the proposed study is a cross-sectional study. We will observe a participants behaviour after playing the different variations of Cyclescapes.

11.2.1 Variables

Dependent Variables

The study should be measuring the player's motivation, level of exertion and game performance. The combination of these 3 variables will help us understand whether the design of Cyclescapes's challenges was a success and potential areas of improvement. To measure motivation, the survey questions found in figure 7.14 should help the experimenter determine the player's overall enjoyment and experience during a session of Cyclescapes. Measuring level of exertion as mentioned in chapter 7 in section 7.1 we will be looking at the player's change in heart rate. There is no accepted method that can accurately estimate the maximum heart rate of a population therefore we cannot use max heart rate % to gauge workout intensity[49]. In terms of the player's in game performance, their score should summarize how well they were able to complete the challenges presented to them.

Independent Variables

For the study to test the effectiveness and the overall success of the game challenges implemented in Cyclescapes to incite physical exertion in the player we have 5 versions of the game.

Version A: This configuration of Cyclescapes has the player pedalling through a virtual bike route that has been imported into the game with no other game mechanics or challenges. All the player needs to be concerned about is either completing the full length of the bike route selected or pedal until the session timer is complete.

The following versions may be impacted by order and may require counterbalancing during the study.

Version B: This configuration of Cyclescapes has all challenges as designed and described in chapter 10 enabled along with the use of an imported virtual bike route. The intent of this version is to determine the effectiveness of the overall design of Cyclescapes.

Version C-1: This configuration of Cyclescapes has only the base challenge mechanic enabled, 10.4.1.

Version C-2: This configuration of Cyclescapes has only the burst challenge mechanic enabled, 10.4.2.

Version C-3: This configuration of Cyclescapes has only the duration challenge mechanic enabled, 10.4.3.

Control Variables

The main control variables for this study is the hardware required by the game. This is limited to the computer, VR head mounted display, bike trainer and heart rate monitor.

The computer specifications will have a non-trivial impact on the participant's experience of Cyclescapes. Switching computers between studies may result in lower performance for running Cyclescapes which may cause a drop in frame rate which is detrimental for a VR experience. With this is mind the base requirements suggested when running Cyclescapes for the study is listed on table 8.5. The computer on the table is the computer used during the development of Cyclescapes and should deliver the intended gameplay experience.

The VR head mounted display should also be consistent between studies and participants. Different VR headsets have different performance outputs. Using the *HTC Vive Cosmos* for all trials should ensure that the Cyclescapes experienced by participants is the intended experience due to it being the development head mounted display used during development. The *HTC Vive Cosmos* should also be used due to it being most practical for the end use environment for Cyclescapes allowing a closer mirroring of the intended use case.

The ANT+ dongle used during development that worked well is the *Garmin Ant+ Usb Dongle*. Depending on the physical set up of the test environment, a USB extension may be required to ensure proper signal reception. The *Elite's Suito* indoor bike trainer, as mention in chapter 8 was used as the pedalling interface of the whole system. Due to the variability of commercial bike trainer capabilities - for the purposes of the study and avoiding redundant set up trials, it is recommended to use the development *Elite's Suito* bike trainer. This will ensure the game functions as designed. The heart rate monitor should also be consistent with respect to on participant placement and hardware unit between studies and participants to ensure consistent accuracy. It is less of a concern to use the same heart rate monitor as we did during development as it seems the ANT+ heart rate monitors send identical information.

Should any of the hardware change during the conduct of the study from the suggested hardware, a test run should be conducted with the new hardware to ensure the full functioning of Cyclescapes.

On the game configuration side of the study, we need to ensure the parameters outside of game challenges stay constant for the duration of the study. This means the route, theme, session duration and target physical intensity level should be consistent. The purpose of this proposed study is to determine the effectiveness of the adapting game challenges for the target audience and the impact they have on the participant.

Confounding Variables

The ergonomics of the bike trainer set up may have an impact of the final results of the study. If the ergonomics of the bike for the participant is incorrect, it will lead to an uncomfortable and potentially difficult to play game which could have an impact on the pedalling efficiency of the participant.

The use of VR may also play a role in affecting the enjoyment of Cyclescapes which in turn may impact the findings. This could be due to the novelty of the technology which the questions in figure 11.5 should be able to screen for. However, a longitudinal study may be required to fully assess the effectiveness of Cyclescapes while minimizing the effects of the technology novelty bias. The use of a VR game may also induce motion sickness. To assess whether or not there is a potential for motion sickness and to all the participant to acclimate to the virtual environment and game controls the participant should pedal through version A of the game for a short duration.

Due to time constraints during development time, a proper tutorial system was not implemented in the current iteration of Cyclescapes during the writing of this thesis. If the participant's in game goals are not effectively communicated by the experimenter to the participant it may impact their in game performance and enjoyment of the game. To minimize and isolate this variable to ensure if there are any effects on the study a script should be written up for the experimenter to give to the participant. This will ensure that all participants are given equal information. The contents of the script must cover all goals the player should have during play. Due to the minimal and focused design as described in chapter 10 the description of player goal's should be quick and easy to digest for any participant.

The environment the study is conducted in may have effects on the results of the test. The concern is the spacing of time between participants within each study. From the exergame literature review conducted in chapter 4, social dynamics in exergames are known to have an effect on the exercise effort output by the player. There are no systems in Cyclescapes that engage the social aspect of gaming, such as competition between players. However the

social aspect may still occur if participants socialize or communicate among themselves between trials. To minimize the impact of social interactions on the results of Cyclescapes it is encouraged to space experiment trials such that participants have little chance to interact with each other. A social environment's effect on the enjoyment and motivation to use an exergame is not what we are testing and designing for in this thesis and for the current iteration of the Cyclescapes project.

Fatigue is a natural consequence of exerting and performing physical activity. Therefore it should be assumed that during the duration of an experiment the participant will get fatigued due to the prolonged use of Cyclescapes. This may cause the tests of each variation of Cyclescapes to interfere with the results of another test. To minimize this it is important to allow the participant breaks between tests. This should help minimize the effects of fatigue between tests for the participant.

11.2.2 Procedure

Before the participants arrive the experimenter is to ensure the game is running and all ANT+ devices, namely the trainer and heart rate monitor are connected to the Cyclescapes system.

When participants arrive they will be provided a survey contain questions regarding their gaming experience, VR experience and physical fitness levels. Should it be required, due to the age of the participant, a guardian may also assist in filling out information on the survey. The experimenter will note down the participants age, gender, height and weight. The basic information of the participant should be recorded as a new player profile within Cyclescapes. This will allow analyses be done after the conduct of the test through the use of in session data. A separate spreadsheet should also be started to capture information that will be relevant for analysis in this study but is not required by Cyclescapes to function. Contact information may be requested but is unnecessary.

After basic information provided by the participant or guardian is recorded, the experimenter should attach the heart rate monitor to the player and record their resting heart rate. To measure the resting heart rate of a patient it is recommended to use an application on a mobile device that can connect to the ANT+ heart rate monitor used during the conduct of the proposed study. This will minimize error between data points as the same device is being used. Once the selected application has determined the participant's heart rate at rest, the experimenter will record this information. The heart rate monitor should be on the participant's arm closest to the ANT+ receiver connected to the computer. Depending of the heart rate monitor used, follow the instruction manual provided by the manufacturer to ensure proper placement and

recommended use of the heart rate monitor.

The experimenter will then assist the participant with getting on the bike used during the study. Adjustments should be made to the vehicle set to accommodate for the participant's height and preferred seating orientation. Once the participant is seated on the vehicle, the experimenter will assist the participant with putting on the VR head mounted display. Adjustments should be made to accommodate for the participant's head shape. The *HTC Vive Cosmos* for example has a dial at the back of the headset that can adjust the tightness of the straps and a dial at the front of the headset, on the face plate that adjusts for pupil distance, making the rendered image more clear. Depending on whether or not a participant is wearing small or large frame glasses, they may be required to remove their glasses for the duration of the tests if it does not fit the cavity within the VR headset. Once the headset is securely on the participant's head, the experimenter will instruct the participant to await further instructions.

Once the player is comfortably set up on the vehicle and is ready to start, the experimenter will ensure the current selected player profile within Cyclescapes is the player to ensure the data collected within the game is organized. Next the experimenter will initiate play session configuration. On this screen the experimenter is able to change different parameters of Cyclescapes. The experimenter will conifgure the pre-test orientation run of Cyclescapes, version A. Disabling all special game challenges, setting the target physical intensity to the agreed upon physical exercise intensity and setting the bike route to the standard route to be used throughout testing for Cyclescapes. The experimenter will then start the game, following on screen instructions for calibrating the player in game orientation and launch the game. During the session the experimenter should only interact with the participant should they be feeling unwell or request for the game to stop.

After the orientation run of Cyclescapes is complete as the participant to fill out a motivation based survey as described in figure 7.14. During this time the participant should be provided a substantial water break. Their post session heart rate should also be captured for comparison with their resting heart rate. The post session heart rate should be captured in a similar fashion to how their resting heart rate was captured.

Once the orientation run of Cyclescapes is complete, the experimenter should introduce the participant to the objective of the game. The ordering of versions the participant will play through will be predetermined by the use of a latin square. Table 11.1 depicts the possible ordering of Cyclescapes configuration settings for participants of the study. For each Cyclescapes session, the experimenter will configure the game to match the descriptions above, in section 11.2.1.

C-1	C-2	C-3	B
B	C-1	C-2	C-3
C-3	B	C-1	C-2
C-2	C-3	B	C-1

Table 11.1: Latin Square for counterbalancing the effects of ordering of Cyclescapes configurations.

After each session of Cyclescapes, the experimenter should record which configuration of the game was played, get the player to fill out the exergame enjoyment survey 7.14 and capture the post session heart rate. Water should be offered to the participant and the participant should be allowed for the full allotted rest time. The experimenter should take the time during the rest period to record important data points of the run such as player score, average power, average heart rate, max heart rate and average speed. This data can be found within Cyclescapes. This cycle of Cyclescapes sessions is repeated until the participant has played through all set configurations of Cyclescapes.

After the experiment is done and all configurations of Cyclescapes has been played through, the experimenter should provide the participant a chance to voice the opinions with regards to their experience with Cyclescapes and conduct a post experiment survey. The goal of the post experiement survey is to assist in the translation of the participant's thoughts regarding the challenges and mechanics employed in Cyclescapes.

11.2.3 Important Considerations

Hygiene

Hygiene is important in keeping participants safe. The testing environment must be cleaned and sanitized between participants. This should include wiping down the hardware the participants have come in contact with and potentially switching out the foam cushioning on the VR headset.

Safety

The experimenter must, for the duration of the experiment be attentive to the needs of the participant. Should the participant describe any discomfort or need to stop during the experiment for any reason, the experiment must be halted and the participant's well being cared for. This may happen due to motion sickness. If this situation occurs, do not force the participant to continue playing. After record the situation details in the experiment notes.

Suggested Test Parameters

As part of the control variables, the session parameters not being tested should be constant. In the interest of time, considering the ages of the potential participants, each "session" of Cyclescapes should be set to 5 minutes in length. As we are also not testing the effects of the route implementation, the pedalling route selected should also be flat with minimal changes in elevation. For target exercise difficulty, the suggestion is to keep the desired difficulty set to medium or low. The important aspect is to keep these parameters consistent for all participants.

Chapter 12

Conclusion

For this thesis, we conducted a cross disciplinary exercise, looking into exercise science, game design, human computer interaction and software engineering to build and exergame for patients that require dialysis treatment due to being under the effects of end-stage renal disease. The current iteration of Cyclescapes uses the knowledge accumulated through literature reviews and commercial product reviews to best create a game that encourages player movement with specialized challenges tailored to the selected mode of exercise and target audience.

The Cyclescapes project was assigned with many requests and constraints mandated to us as developers and designers from the pediatric research team. Exergames can come in many formats as shown by our review of a sample of commercially available exergames. This would mean there are many different input options as designers. Due to or project mandates options was not a luxury we were afforded. Due to the many project mandates we had defined boundaries to work within to design Cyclescapes. The difficult aspect of creating a game in Cyclescapes was designing a game that was enjoyable but also met the needs of the two core stakeholders, the patients who will be playing the game and the pediatric researchers, who needed the game to conduct their own research in regard to VR, exergaming and encouraging exercise in sedentary youth. This did allow us to better dissect the design process of exergames, giving us a better understanding of how to build an exergame and what to consider from design to implementation.

12.1 Cyclescapes Analysis

Similar to chapter 6, this section of the conclusion provides a quick overview and anecdotal analysis of the current Cyclescapes version, as of writing this thesis. The anecdotal analysis largely pulls from informal player testing done by friends and colleagues willing to help us with the development of the project.

Though not a formal study it should provide insight to the effectiveness of the current design of Cyclescapes.

Cyclescapes is an *exercise driven* exergame that does not make use of an exercise protocol. Cyclescapes is uses VR technology and an ANT+ based indoor bicycle trainer to capture the exertion of its player. The player plays Cyclescapes by wearing the VR head mounted display while riding a bike. Cyclescapes is designed for a large age demographic spread of 6-18.

The exercise in Cyclescapes is 1 dimensional. The player only has control over their pedalling, being able to pedal faster or slower but not changing directions. The bicycle trainer used in Cyclescapes can also generate resistance, making pedalling require more effort by the player. All other physical movement captured by the VR headset does not contribute to the game and its challenges. The VR position and orientation control allows the player to readjust their in game view.

All of the game mechanics and challenges for the player in Cyclescapes are centred on the player's pedalling. The core focus for the player is to collect the gems by completing the game's challenges. The challenges employed by Cyclescapes are based off our challenge extension of Adams's challenges for exergames described in chapter 7. All game mechanics require the player to pedal forward along the generated level. The burst gem challenge incites increased unsustainable level of exertion for a short duration, a Power based challenge. The base gem challenge as well as the bike route the level is generated based on requires prolonged exertion testing a player's endurance. The duration gem challenge combines both power and endurance challenges by requiring a player to increase their exertion but not to the degree of a burst gem challenge. The game's challenges are mutually exclusive, allowing the player to focus on the current task, completing it before another challenge is presented.

The real world route data allows the game to recreate the slope of a path through manipulation of the indoor bicycle trainer's resistance.

Cyclescapes attempts to encourage players to exercise through its challenges. All objectives in the game require the player to move forward. The player's performance is directly tied to how well they complete the game challenges. Cyclescapes does not punish the player by means of reducing score, rather the game removes the opportunity to score relative to game challenges. If a player pedals at a reduced rate their score will be lower as a consequence, due to being unable to collect the same number of gems when compared to a player pedalling faster.

Initial sessions of Cyclescapes will also encourage the player to move through the use of exploration. Pedalling moves the player along a track, providing the player new sights within the virtual world taking advantage of VR. This sense of exploration may lessen as the player plays Cyclescapes more as the current iteration of Cyclescapes does not have enough map resources to sustain an

infinite, non-repeating virtual environment.

Cyclescapes allows the target exercise intensity adjusted between 3 different settings; low, medium and high intensity. Each game challenge is also optional. This allow players to define what kind of challenges they would like to face for the duration of the game. The route imported into the game and selected by the user will also adjust the physical exercise difficulty of Cyclescapes. Since the real world data is translated into the resistance felt by the player while pedalling, a more difficult selected course - namely routes with more inclines will yield a more difficult and exhausting Cyclescapes session. This allows the player to alter the baseline physical exercise difficulty.

The game mechanics in Cyclescapes also noticeably change pedalling speed requirements for completion. A player able to pedal more quickly will see that the duration and burst gem challenges adjust to be quicker than the player within a certain range. As the player demonstrates that they are able to consistently increase their speed and physical exertion the game will adjust the challenges to match. The same would happen if the beginner becomes fatigued or is otherwise slowed down.

Cyclescapes as an exergame may have too much focus on the act of pedalling with all gameplay directly tied to the exercise. The audience for Cyclescapes matches the audience of the research proposed by the pediatric research team and assumes the participant is already a willing participant for playing the game. Based on the informal reviews of the product by volunteers, the game seems to be enjoyable but may lack the complexity and gameplay options that will allow for long term engagement by a general audience. The proposed user study and perhaps a longitudinal variant of the study will better assess the fun factor of Cyclescapes for both short and long term use.

12.2 Discussion

The purpose of this thesis is to understand how to adapt games to the physical and gaming abilities of a player who must play the exergame. Through literature reviews, commercial product reviews and the development of Cyclescapes we have arrived at some considerations a designer should make when approaching the task of design an exergame with a specific audience and purpose, such as the Cyclescapes purpose of enabling sedentary children to being active.

12.2.1 Exergame Design Questions

During the literature review portion of this journey, we found no papers to our knowledge that helped guide our process in designing an exergame and adapting it to our target audience. The following set of questions aims to help designers ask critical questions to fully grasp what they are intent on

implementing. The reason a set of questions was chosen was because during the writing of this thesis - asking more questions inspired the solution we arrived at whether it be for writing or development.

Exercise Input

Determine and understand the method of exercise input that will be used for the exergame. The following are questions a designer should ask when considering the movement input for an exergame.

1. What aspects of the movement should be quantified?
2. What is the range of motion afforded by the input method?
3. Are certain movements not allowed?
4. Is there a specific way the movement should be done?
5. What can make the selected movement difficult?

Target Audience

When designing an exergame for a specific target audience, a designer must understand the physical fitness limits of the target audience. It is beneficial to understand the expectations of the target audience to better tailor the player experience to meet the purpose of the project and the needs of its players.

1. Who is the game being made for?
2. What is the expected physical fitness level of an average player?
3. Is the required movement difficult for a player?
4. Does the target audience play video games?
5. What experience does the target audience have with the technology used?

Game Driver

The game driver for an exergame refers to the definitions of *Game Driven* and *Exercise Driven* introduced in chapter 6. The game driver is the guiding hand behind the design of the exergame. It should inform the designer what is the target player experience. For a *Game Driven* exergame the act of exercising is a consequence of the game's mechanics and challenges. In an *Exercise Driven* exergame, the game's challenges are centred around movement required by the game.The following will help a designer determine the experience their exergame should have.

1. Are there actions or tasks for the players to complete that do not directly relate to the act of exercise?
2. How much of the player's attention will be directed explicitly at the exercise?
3. Will the exercise movements done by the player map to real world expectations?

Challenge for Exertion

Once the designer understands the bounds of the exercise input and how exercise is approached within their exergame they must look to designing the challenges such that a player's ability, physical or game related can be used as input. This should use the quantifiable aspects identified during their exercise input questioning period. When designing the challenge for the exergame, the following questions should have answers.

1. What does the metric captured of the player's movement mean?
2. What are the objectives of the exergame and how do they engage the player physically?
3. How do the rules of the exergame's challenge(s) relate to the physical input metric? What does a favourable performance look like? What does poor player performance look like?
4. How does the game system quantify the performance of a player relative to the challenge presented to the player?

12.3 Future Work

12.3.1 Future Studies

The research journey for Cyclescapes gave us many aspects that will require more study to fully understand the implications they had on the Cyclescapes we developed. There are three other components required of the Cyclescapes due to the research proposal Cyclescapes was conceived under that could help us fully understand the design of exergames.

The first component that should be studied is the use of VR in an exergame as compared to more traditional variants of exergaming. For this study, it would need to be designed to test the effectiveness of VR to get player's to engage with an exergame. A longitudinal study is recommended for future

study of this nature to best determine the impacts of technology novelty. Does VR gaming lend itself to a more engaging exergaming experience?

The second aspect of Cyclescapes that was required as part of the project description is the use of real world data. Real world data was used to provide players a sense of familiarity to the game and at the same time allow the player to test there physical ability on a path they may traverse in the real world as a controlled test. In regard to the design of an exergame it is unknown to our knowledge whether the use of real world data makes for a better exergame. Or does the use of real world data make no to little impact to the enjoyment and exertion by the player during a gameplay session. Designing a method to use real world data can be time-consuming therefore understanding the impacts of such designs may better inform more impactful design choices. To make the expansion to such a topic more applicable to the Cyclescapes audience, a user study should be conducted under the same audience parameters. Is the use of real world data an appropriate technique to adapting exergames to the player?

The third aspect of Cyclescapes and one we encountered upon during the design process is the mapping of player movement to expected consequences. In hopes of creating a more game driven experience we looked towards the idea of mapping game inputs to more unexpected actions. An example would be mapping the pedalling of the bicycle trainer to the reeling in of a fish or a fishing pole. By not having the act of pedalling tied to the in game action of player movement, more creative designs and challenges could be invented for Cyclescapes. The question of impact of input mapping in an exergame was partially inspired by the mini-games available in *Ring Fit Adventure*. Learning and studying the impact of input mapping in exergames may lead to more innovative challenge designs potentially leading to a more engaging and entertaining exergame. Does the use of indirect mapping of movement input to game actions allow for a more interesting and engaging player experience for exergames?

12.3.2 Future for Cyclescapes

The future of Cyclescapes design and implementation first requires the conduct of the proposed user study to assess and formally review the current design and implementation. Depending on the data received new features may require investigation and development time. What is for certain is that the current parameters the Cyclescapes mechanics are set for require more tuning and balancing to make the challenges enjoyable and engaging.

Based on our review of exergames the next big feature that allow for more player engagement is the addition of social elements.

During the development of Cyclescapes, the trainer and bicycle set up used

for testing and informal player testing was temporary. However due to the delays caused by the Covid-19 global pandemic we were unable to obtain and use the intended stationary tricycle. Figure 12.4 is an image of the prototype trike that was intended to be used during the development and testing of Cyclescapes.

Figure 12.4: End user trike for in clinic Cyclescape use.

The difference between a regular, 2 wheeled bicycle and the intended tricycle had a significant impact to the design of Cyclescapes. Due to the ergonomics of the bike demanding more balance of the player, keeping in mind our target audience, the design choice of removing the VR controllers for the sake of the player's balance meant less input options for the player. With the tricycle offloading the balance task from the player to the hardware, the player should be able to use at least 1 free hand for manipulating a VR controller. This opens up the potential for alternative methods of adding more gameplay mechanics that can engage the player in more ways than just pedalling. This will require more time for future developers of Cyclescapes to revisit the drawing board to see where the potential of Cyclescapes can lead.

Bibliography

[1] (2016). Hot squat.

[2] (2016). Pokemon go: Frequently asked questions.

[3] (2019). Ring fit adventure - nintendo - official site.

[4] (2020). How do zombie chases work? i keep getting caught!

[5] (2020). Physical activity guidelines world health organization.

[6] (2020). Vive cosmos specs: Vive canada.

[7] (2021). Garmin usb ant+ stick.

[8] (2021). *Nintendo: Financial Results Explanatory Material*.

[9] Adams, E. (2014). *Fundamentals of game design*. Pearson Education.

[10] Alderman, N. (2012). Zombies, run!

[11] Althoff, T., White, R. W., and Horvitz, E. (2016). Influence of pokémon go on physical activity: study and implications. *Journal of medical Internet research*, **18**(12), e315.

[12] aXiom, A. (2021). Available through steam only!

[13] Bannert, M. (2002). Managing cognitive load—recent trends in cognitive load theory. *Learning and instruction*, **12**(1), 139–146.

[14] Baxter-Jones, A. D., Eisenmann, J. C., and Sherar, L. B. (2005). Controlling for maturation in pediatric exercise science. *Pediatric Exercise Science*, **17**(1), 18–30.

[15] Caspersen, C. J., Powell, K. E., and Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports*, **100**, 126–31.

[16] Coggan, A. R. (2017). Training and racing using a power meter: an introduction. *URL http://www. ipmultisport. com/ref_lib/Coggan_Power_Meter. pdf. Accessed*, **8**.

[17] Csikszentmihalyi, M. and Csikzentmihaly, M. (1990). *Flow: The psychology of optimal experience*, volume 1990. Harper & Row New York.

[18] Dave, H. D., Shook, M., and Varacallo, M. (2020). Anatomy, skeletal muscle. *StatPearls [Internet]*.

[19] Drummond, D. (2019). Risk of rain 2.

[20] Eijsermans, R. M., Creemers, D. G., Helders, P. J., and Schröder, C. H. (2004). Motor performance, exercise tolerance, and health-related quality of life in children on dialysis. *Pediatric Nephrology*, **19**, 1262–1266.

[21] Farič, N., Potts, H. W., Hon, A., Smith, L., Newby, K., Steptoe, A., and Fisher, A. (2019). What players of virtual reality exercise games want: thematic analysis of web-based reviews. *Journal of medical Internet research*, **21**(9), e13833.

[22] Fitzgerald, A., Huang, S., Sposato, K., Wang, D., Claypool, M., and Agu, E. (2020). The exergame enjoyment questionnaire (eeq): An instrument for measuring exergame enjoyment. In *Proceedings of the 53rd Hawaii International Conference on System Sciences*.

[23] Games, H. (2019). Risk of rain 2.

[24] Gil, L. (2020). Ring fit adventure is perfect for lazy, sedentary people like me.

[25] Greenwald, W. (2019). Htc vive cosmos review.

[26] Howe, K. B., Suharlim, C., Ueda, P., Howe, D., Kawachi, I., and Rimm, E. B. (2016). Gotta catch'em all! pokémon go and physical activity among young adults: difference in differences study. *bmj*, **355**.

[27] Huh, Y., Duarte, G. T., and El Zarki, M. (2018). Minebike: Exergaming with minecraft. In *2018 IEEE 20th International Conference on e-Health Networking, Applications and Services (Healthcom)*, pages 1–6. IEEE.

[28] Iqbal, M. (2021). Pokémon go revenue and usage statistics (2021).

[29] Jamnick, N. A., Pettitt, R. W., Granata, C., Pyne, D. B., and Bishop, D. J. (2020). An examination and critique of current methods to determine exercise intensity. *Sports Medicine*, **50**, 1729–1756.

[30] Jayaseelan, G., Bennett, P. N., Bradshaw, W., Wang, W., and Rawson, H. (2018). Exercise benefits and barriers: the perceptions of people receiving hemodialysis. *Nephrology Nursing Journal*, **45**(2), 185–219.

[31] John, A. (2019). Ring fit adventure - what does a professional trainer think about this workout game?

[32] Karvonen, J. and Vuorimaa, T. (1988). Heart rate and exercise intensity during sports activities. *Sports Medicine*, **5**, 303–311.

[33] Kimmel, P. L. and Patel, S. S. (2006). Quality of life in patients with chronic kidney disease: focus on end-stage renal disease treated with hemodialysis. In *Seminars in nephrology*, volume 26, pages 68–79. Elsevier.

[34] Kolasinski, E. M. (1995). *Simulator sickness in virtual environments*, volume 1027. US Army Research Institute for the Behavioral and Social Sciences.

[35] Laforge, R. G., Rossi, J. S., Prochaska, J. O., Velicer, W. F., Levesque, D. A., and McHorney, C. A. (1999). Stage of regular exercise and health-related quality of life. *Preventive Medicine*, **28**(4), 349–360.

[36] Levesley, D. (2020). Ring fit adventure is a great workout with an ingenious approach.

[37] Lindsey, J. and Nystrom, M. (2021). Your straightforward guide to understanding power meter metrics.

[38] MacKenzie, I. S. (2012). Human-computer interaction: An empirical research perspective.

[39] Macvean, A. and Robertson, J. (2013). Understanding exergame users' physical activity, motivation and behavior over time. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1251–1260.

[40] Nakamura, J. and Csikszentmihalyi, M. (2009). Flow theory and research. *Handbook of positive psychology*, pages 195–206.

[41] Niantic, Nintendo, T. P. C. (2016). Pokemon go.

[42] O'Connor, J. (2016). Superhot vr looks super hot.

[43] Oh, Y. and Yang, S. (2010). Defining exergames & exergaming. *Proceedings of meaningful play*, **2010**, 21–23.

[44] Pallavicini, F., Ferrari, A., Zini, A., Garcea, G., Zanacchi, A., Barone, G., and Mantovani, F. (2017). What distinguishes a traditional gaming experience from one in virtual reality? an exploratory study. In *International Conference on Applied Human Factors and Ergonomics*, pages 225–231. Springer.

[45] Pallavicini, F., Pepe, A., and Minissi, M. E. (2019). Gaming in virtual reality: what changes in terms of usability, emotional response and sense of presence compared to non-immersive video games? *Simulation & Gaming*, **50**(2), 136–159.

[46] Patel, H., Alkhawam, H., Madanieh, R., Shah, N., Kosmas, C. E., and Vittorio, T. J. (2017). Aerobic vs anaerobic exercise training effects on the cardiovascular system. *World Journal of Cardiology*.

[47] Porter III, J., Boyer, M., and Robb, A. (2018). Guidelines on successfully porting non-immersive games to virtual reality: A case study in minecraft. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, pages 405–415.

[48] Riebe, D., Ehrman, J. K., Liguori, G., Magal, M., of Sports Medicine, A. C., *et al.* (2018). *ACSM's guidelines for exercise testing and prescription*. Wolters Kluwer.

[49] Robergs, R. A. and Landwehr, R. (2002). The surprising history of the" hrmax= 220-age" equation. *Journal of Exercise Physiology Online*, **5**(2), 1–10.

[50] Rothmann, R., Smith, J., Marais, M., Wolthers, L., Strauss, D., Orekhov, F., Sutherland, J., Strauss, S., and Amirkhani, J. (2019). Gorn.

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

[52] Schjerlund, J., Hansen, M. R. P., and Jensen, J. G. (2018). Design principles for room-scale virtual reality: A design experiment in three dimensions. In *International conference on design science research in information systems and technology*, pages 3–17. Springer.

[53] Shaw, L. A., Wünsche, B. C., Lutteroth, C., Marks, S., and Callies, R. (2015). Challenges in virtual reality exergame design.

[54] Shelstad, W. J., Smith, D. C., and Chaparro, B. S. (2017). Gaming on the rift: How virtual reality affects game user satisfaction. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 61, pages 2072–2076. SAGE Publications Sage CA: Los Angeles, CA.

[55] Sinclair, J., Hingston, P., and Masek, M. (2007). Considerations for the design of exergames. In *Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia*, pages 289–295.

[56] Soraine, S. (2018). *Ooh What's This Button Do?* Ph.D. thesis.

[57] SUPERHOT (2019). Superhot vr.

[58] Sweetser, P. and Wyeth, P. (2005). Gameflow: A model for evaluating player enjoyment in games. *Comput. Entertain.*, **3**(3), 3.

[59] Tang, A. K. (2017). Key factors in the triumph of pokémon go. *Business Horizons*, **60**(5), 725–728.

[60] Taylor, J. (2009). Proprioception. In L. R. Squire, editor, *Encyclopedia of Neuroscience*, pages 1143–1149. Academic Press, Oxford.

[61] to Start, S. (2012). Zombies, run!

[62] Tran, P. T. K. (2020). Design and evaluation of techniques to improve user comfort during prolonged use of virtual reality.

[63] van Bergen, M., Takken, T., Engelbert, R., Groothoff, J., Nauta, J., van Hoeck, K., Helders, P., and Lilien, M. (2009). Exercise training in pediatric patients with end-stage renal disease. *Pediatric Nephrology*, **24**, 619–622.

[64] Whaley, A. (2017). Evercycle"-a virtual reality exercise game to accelerate exercise performance improvement using the "feedforward effect.

[65] Whitehead, A., Johnston, H., Nixon, N., and Welch, J. (2010). Exergame effectiveness: what the numbers can tell us. In *Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games*, pages 55–62.

[66] Yoo, S., Carter, M., and Kay, J. (2018). Vrmove: Design framework for balancing enjoyment, movement and exertion in vr games. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, pages 295–307.

[67] Zeng, N., Pope, Z., and Gao, Z. (2017). Acute effect of virtual reality exercise bike games on college students' physiological and psychological outcomes. *Cyberpsychology, Behavior, and Social Networking*, **20**(7), 453–457.

[68] Zheng, J., Chan, K., and Gibson, I. (1998). Virtual reality. *Ieee Potentials*, **17**(2), 20–23.

[69] Zwift (2014). Zwift.