COMPUTER-AIDED EXERCISE

by

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Abstract

An underlying goal of designers of some exercise video games is to increase people’s motivation to exercise. Research in the field of exercise psychology shows that performing physical activity in groups increases exercise participation and adherence. However it is unclear whether the benefits of grouping apply to video games involving physical activity.

This research investigates whether the motivational benefits of grouping translate to exercise games. We experimentally validate three properties of collaborative exercise games. Experiments were performed using a custom exercise game, designed with game requirements intended to increase exercise motivation. We discovered that the exercise enjoyment and engagement benefits of grouping do translate to exercise games: players preferred collaborative over single-player exercise games, and found our collaborative exercise game equally enjoyable and engaging in both co-located and distributed settings. Most interesting, non-exercisers and exercisers found the game equally enjoyable and engaging.

These results indicate that collaborative exercise video games are a promising approach to helping with exercise enjoyment and engagement, and that developers should consider incorporating multiplayer support into their exercise games.
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Chapter 1

Introduction

The rate of obesity has more than doubled for people ages 25-34 over the last two decades [22]. 51% of Canadians are inactive [23] and this may be attributed to our increasingly sedentary lifestyle [51]. Unless people become more active, it is likely that the obesity rate, as well as its associated health risks of heart disease, stroke, and diabetes, will continue to rise [6, 5, 60].

Video games involving an exercise component show promise in helping to avert the obesity crisis. Sixty-nine percent of American heads of households play computer and video games [1]. As many people already enjoy games, combining the fun of video games with exercise appears to be a natural path to promoting exercise.

There is anecdotal evidence of the potential success of exercise games. For instance, the commercial success of Dance Dance Revolution [42] and Wii Sports [62] show that it is possible to create fun games containing an exercise component. However, it is not well understood what makes an appealing exercise game. There is to-date limited research into the factors that lead some exercise video games to succeed while others fail.
This thesis examines whether the motivational benefits of group exercise apply to people playing collaborative exercise video games. It is known that players enjoy the social aspects of multiplayer computer games [74]. Modern computer games are predominantly multi-player. Gamers usually play over a network from different locations, whereas people participating in a sport are all in the same place. We experimentally investigated the motivational benefits of group exercise embedded within exercise video games. The results of our experiments lend support to three broad conclusions:

- People find collaborative exercise video games more enjoyable and engaging than single-player exercise video games.
- Distributed group exercise is just as enjoyable and engaging as co-located group exercise.
- People who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers.

Our focus on the collaborative aspect of exercise was influenced by our examination of existing exercise games and the exercise motivation literature. Existing exercise games provided examples of how to embed exercise into video games. The exercise motivation literature revealed numerous factors affecting exercise motivation, including increased exercise participation and adherence through grouping.

1.1 Exercise Games

This section highlights some examples of existing exercise video games. In Breakout for Two, two friends located in different cities can play a game of soccer via a virtual
screen [56]. Groups of players can explore an imaginary underwater environment in Nautilus [73]. In Human Pacman, the real and virtual worlds merge as players play a life-size version of Pacman [25]. Finally, FlyGuy simulates hang gliding by physically strapping players into a hang glider frame [57].

These games show different ways of embedding exercise into video games. Some of these games were created to increase immersion, and provide new styles of play. An underlying goal of many of these exercise games is to improve peoples’ motivation to exercise. The idea is that people may enjoy exercise by combining the fun of games with physical activity. However, there has been little attempt to analyze what makes a successful exercise video game. Thankfully, there is a breadth of literature that examines factors that affect exercise motivation in general. Such factors form the basis for game requirements which may result in successful exercise video games.

1.2 Exercise Motivation

Exercise games show promise in increasing peoples’ motivation to exercise. Warburton et al. have demonstrated that a single-player racing game using a stationary bicycle provided greater exercise adherence than using the stationary bicycle on its own [79]. Graves et al. have shown that popular games can provide exercise benefits - Wii Tennis provides about half the caloric burn of real tennis, and about five times more than traditional sedentary games [37]. This provides encouraging evidence that integrating games with exercise can increase exercise motivation while providing beneficial exercise.

Although exercise video games appear to increase exercise motivation, it is important to understand the factors that affect exercise motivation. The literature revealed
five factors: music, instructor, exercise role-identity, peer support, and self-efficacy, that affect people’s motivation to exercise. These factors have been shown to affect exercise motivation in traditional exercise. Using these factors, we created a list of game requirements. Exercise video games should:

- Integrate music
- Hide players’ fitness level
- Provide achievable short and long term goals
- Facilitate leadership for novice players
- Remove barriers to grouping
- Actively assist players in forming groups

We illustrate these requirements using two exercise video games. Life is a Village, uses game requirements intended to increase long term exercise motivation. The second game, Frozen Treasure Hunter illustrates how multiplayer game requirements can be implemented.

After examining the exercise motivation literature and developing a set of game requirements, we decided to focus on questions pertaining to collaborative exercise. Much of the literature touts the benefits of grouping, mainly that exercising in groups increases exercise adherence and participation. These are desirable qualities for exercise video games. However, little research has been performed to determine if these benefits apply to exercise video games. This thesis demonstrates that exercise video game players accrue the same motivational benefits as traditional group exercise.
1.3 Results

We performed two experiments using Frozen Treasure Hunter to investigate our hypotheses. The first experiment had players play multiplayer and single player versions of the game. Players were then asked to answer questionnaires intended to measure enjoyment, engagement, exercise self-efficacy, and team sports participation. Our results indicated nine out of ten players preferred multiplayer over single player. Players were also significantly more engaged with the multiplayer version of the game. These results support our hypothesis that players prefer multiplayer over single player exercise games.

The second experiment had players play co-located and distributed versions of the game. Preference of co-located and distributed play was equally split between players. Enjoyment and engagement scores were equally high for both versions of the game. This implies that distributed group exercise is just as motivational as co-located group exercise.

Players’ preference of co-located or distributed play was not affected by their exercise self-efficacy or team sports participation scores. This supports our hypothesis that both exercisers and non-exercisers equally enjoy exercise games. Unlike traditional exercise, where low exercise self-efficacy correlates with low exercise enjoyment [69], people view the physical activity of exercise video games differently. These results show promise in introducing non-exercisers to physical activity with exercise video games.
1.4 Contributions

This thesis offers the following contributions:

- Showed that players of an exercise video game enjoy multiplayer over single player gameplay and are more engaged.

- Showed players’ equal enjoyment and engagement benefits of distributed and co-located exercise video games.

- Showed players’ equal enjoyment and engagement of collaborative exercise games amongst exercisers and non-exercisers.

- Developed game requirements intended to increase exercise motivation in exercise video games.

- Designed and implemented a multiplayer exercise video game.

1.5 Outline

This thesis is organized as follows. Chapter 2 provides a review of existing exercise games and the exercise motivation literature. There are many exercise games, both academic and commercial. We classify these games via a taxonomy based on the game’s user interface and game world. To understand how to encourage people to exercise in games, we must first examine what motivates people to exercise with traditional exercise. Therefore in chapter 2, we also review aspects of the exercise motivation literature. Through our discussion of the literature, we identify several
factors (barriers to grouping, peer support, self-efficacy) that affect people’s motivation to exercise. These findings led to the development of a set of game requirements which we present in chapter 3.

Chapter 3 discusses how motivational factors in the exercise motivation literature can be applied to game requirements. We provide a list of these game requirements and determine how they can benefit future exercise games. We illustrate how these game requirements can be realized through analysis of Life is a Village (a pre-existing exercise game) and Frozen Treasure Hunter, a novel game that I developed. Implementation details about Frozen Treasure Hunter are briefly examined in chapter 5.

Chapter 4 experimentally investigates our hypotheses on collaborative exercise video games. Experiments performed with Frozen Treasure Hunter suggest that players prefer multiplayer over single-player exercise video games. Players equally enjoy and are engaged in distributed and co-located versions of Frozen Treasure Hunter. We also discover that both exercisers and non-exercisers equally enjoy exercise video games.

These results strongly encourage game developers to incorporate multiplayer components into exercise games. Ideally, exercise games should have both distributed and co-located multiplayer options, providing players with the ability to exercise in any setting. However, if developers are forced to choose only one setting, either choice is equally beneficial to players. Furthermore, developers can be reassured that it is possible to design exercise video games that appeal equally to players with low and high exercise self-efficacy.
Chapter 2

Background

Recently, there has been much activity in combining video games and exercise. Commercially, games such as *Wii Sports* [62] and *Dance Dance Revolution* [42] have proven that this combination can result in a novel, engaging experience. For instance, Tennis in *Wii Sports* has been shown to provide exercise benefits, providing half the caloric burn of real tennis [37]. However, even with these successes, it is unclear what design features lead to exercise games that motivate people to exercise. The purpose of our research is to understand what multiplayer game factors contribute to or detract from peoples’ motivation to perform exercise.

In the exercise motivation literature, extensive research attempts to understand how to motivate people to begin and maintain exercise programs. Enjoyment is commonly mentioned as a factor in motivating people to adhere to exercise programs [81, 78, 35, 4]. As we shall see, the literature suggests that low exercise compliance is linked with poor exercise self-efficacy (person’s belief in their ability to overcome obstacles related to exercise), lack of leadership, and peer support. Understanding these results is crucial to understanding the ways in which computer games can help
Exercise video games are created in a number of fields within computer science such as human-computer interaction, ubiquitous computing, and games researchers. Terminology used to describe exercise video games is inconsistent. Terms such as “exergaming” or “exertion interfaces” are commonly used. After examining multiple papers on exercise video games, we created a survey containing consistent terms for games from both the commercial and academic spheres. This survey covers a wide range of games, and provides a glimpse into the new gaming experiences possible. An underlying goal of many exercise games is to improve people’s motivation to exercise [79]. We will discuss the exercise motivation literature to understand factors that affect exercise motivation.

### 2.1 Exercise Games

We created a taxonomy (figure 2.1) to categorize different types of games by the degree and form of support for exercise. This taxonomy was created by examining papers
and research on existing exercise video games as well as playing some (Wii Sports, Dance Dance Revolution, Laser Tag). These games ranged from traditional video games played with gamepads, to games where body motion is used. Different user interfaces require different styles of physical exertion. In addition to using different user interfaces, games can be categorized based on the world they present to players. Games can be presented to the player in various forms. Traditional games such as soccer are played on a field in the real world. On the other hand, most video games are played within a computer-simulated environment. We begin our look at exercise games by defining the terms game world and user interface. We then step through our taxonomy to describe the many exercise games possible.

2.1.1 Game World

Games, both traditional and digital, are set in a game world comprised of characters, objects, and an environment. Game worlds fall on a continuum between the purely virtual and the purely physical (or “real”). Between these extremes fall hybrids known as augmented reality.

We begin with the most familiar game world, reality, where all aspects of the game exist in the real world. These aspects include the players, the environment around them, and the objects they interact with. Examples include traditional sports such as soccer or basketball. Others include less physically intense games such as chess or checkers. In their traditional forms, these games involve no interaction with computers.

On the other end of the game world continuum is the completely virtual world. A virtual world is an environment generated entirely within a computer. Players use a
display device to act as a portal to the virtual world. Most commercial games, (e.g. Pacman (figure 2.2)) are based on virtual worlds [18]. The characters, objects, and maze all exist virtually, and are presented to the player via a display.

The third type of game world is augmented reality. Augmented reality combines a real scene, such as the world around us, with a virtual scene generated by a computer. Virtual elements can then appear to exist in the real world. In the game of laser tag (figure 2.3), players run around an enclosed space, shooting each other with infrared light. Players wear sensors which register infrared light. When a player is shot, LEDs on the sensor light up to indicate a virtual hit. Although the hit is not real, it gives the impression that the victim is wounded from a laser blast. These virtual hits are an example of how the physical world can be augmented with virtual elements.
2.1.2 User Interface

Our second method of categorizing games is through their user interface. Players provide input and interact with the game world through the user interface. Due to our interest in exercise video games, we categorized user interfaces based on their required physical exertion. Traditionally, games are controlled with a keyboard and mouse or some type of game pad. We call this a traditional electronic interface. Button presses and joystick movements trigger events in game. With this type of interface, little to no physical exertion is required. Therefore such a user interface would not be suitable for exercise video games. Almost all commercial games use traditional electronic interfaces. Referring again to Pacman, players control the character’s movement by moving a joystick in four different directions.

Conversely, with equipment-based physical interfaces (e.g. a stationary bicycle or treadmill), significant physical exertion is required to trigger events in game. The
interface is both the source of input and exercise. Equipment-based physical interfaces have a limited range of motion for input. Players are required to perform specific motions in order to properly operate the input device. For instance, with GameBike (figure 2.4) [34], players control games by pedaling on a bicycle. GameBike is used primarily with racing games where pedaling speeds determine a car’s speed. Because users are required to sit on the bike and produce pedaling motions, this interface is more restrictive than free-motion interfaces. Equipment used by this interface is not portable because of its size and weight.

Free-motion interfaces allow the user to move about freely while performing actions in game. Players’ motions are not restricted by the input device. Devices such as cameras, accelerometers, or pressure sensors can be used to capture user input. For instance, in Wii Tennis, players play a game of tennis by swinging a motion sensitive
Wii Remote in their hand. Players can choose to perform long strokes with great body movement, or make quick wrist flicks to control the game. Because free-motion interfaces allow such a great range of motion, large spaces may be required to ensure players do not bump into objects. Equipment used by free-motion interfaces are portable, allowing players to easily move to different locations.

Game worlds can be completely virtual, a mix of virtual and physical, or entirely physical. Similarly, interfaces can be traditional, equipment-based, or free-motion based. Unique games can be created depending on how the game world and user interface are combined. Some combinations result in exercise games. Other combinations are still open for research. Before discussing some of the more virtual game worlds, we examine how the physical world, or reality, is used as a game world.

## 2.1.3 Reality-Based Games

Of the three game worlds, players should be most familiar with the world around them. In this game world, all aspects of the game (players, environments, and objects) exist in the real world. Referring back to our taxonomy, we will now discuss games in the entire “reality” row in figure 2.1.

*Soccer* is an example of a game that employs a free-motion interface in the real world. The goal of soccer is to kick a ball into an opposing team’s net. To do this, players are free to move about however they choose. Their motions are not restricted by the ball. Players may hit the ball with any part of their body except their hands. It is this freedom of motion that categorizes soccer as a reality-based free-motion interface in reality.

*Cycling* is an example of an equipment-based physical interface situated in the real
world. The game world is the physical terrain around the cyclist, while the interface is the bicycle. To properly operate a bicycle, cyclists are restricted to sitting and pedaling.

An example of a traditional electronic interface is a radio controlled (RC) car. RC cars are physical miniature cars which can be controlled by an electronic hand held device. Players control the steering and acceleration of the car by pushing buttons and joysticks on their hand held device. All aspects of RC racing occur in the real world. The car and electronic device are real. We do not classify the electronic device as a free-motion or equipment-based physical interface because it requires almost no physical exertion to operate.

Soccer, cycling, and RC cars are all activities that take place in the real world. These examples were presented to introduce the concepts of game worlds and user interfaces to familiar activities. Now that we have categorized reality-based games, we will continue along the taxonomy by discussing hybrid games using augmented reality.

2.1.4 Augmented Reality with Free-Motion Interface

A free-motion augmented reality game overlays elements of the virtual world onto the real world. This gives the illusion that virtual world objects exist in the real world. To control the game, players freely move their body. Free-motion interfaces translate physical movements into corresponding actions in the game.

In the augmented reality laser tag game, players wear suits embedded with LEDs. These LEDs light up when players are hit. The LEDs are used to express a virtual hit.
In the game Human Pacman, players play a game of Pacman in the physical world. Instead of controlling Pacman using a joystick, players wear a mobile computer fitted with a head mounted display. This display places virtual objects in the player’s surroundings, giving the illusion that game objects exist in the real world (figure 2.5). For instance, game elements, such as collectable pellets, appear to hover in the physical environment. Since this is a free-motion interface, players physically walk around their environment to pick up the pellets. Other players take on the role of Ghosts in the game. Her goal is to “consume” Pacman by physically tapping his shoulder.

In Age Invaders (figure 2.6), players shoot each other with rockets. Players play the game by stepping on a pressure sensitive board embedded with LEDs. When players fire their toy gun, LEDs on the floor light up in the shape of a rocket. Hostile
rockets can be dodged by walking to different areas of the game board. By augmenting reality with LEDs, virtual games can be played in a physical space.

The advantage of free-motion augmented reality games is that they allow people to play video games incorporated into the real world. The free-motion interface allows players to become a character in the game, rather than controlling one via a user interface. Disadvantages of this type of game are safety issues and implementation difficulties. In Human Pacman, players physically walk outside in the real world. Players may become distracted by virtual objects and be unaware of oncoming traffic. Free motion interfaces are also difficult to implement. Age Invaders requires a custom LED embedded surface, and Human Pacman requires complex wearable computers.
2.1.5 Augmented Reality with Traditional Electronic and Equipment-Based Physical Interfaces

Human Pacman and Age Invaders are examples of free-motion augmented reality interfaces. However, we could not find examples of games that used augmented reality with traditional electronic or equipment-based physical interface. Perhaps this is an avenue for further research possibilities.

Imagine a game where a player cycles through a foreign countryside. As she glances to her left, she sees her cycling partner coaching her to stay in formation. Her partner is beginning to get too close, so she reaches out to brace for impact. However, there is no one actually there. The cyclist’s partner is part of the augmented reality projected on to her head mounted display. She is taking a real life tour of a countryside with a virtual tour guide. The equipment-based interface she is using is a real bicycle. This might be an example of a game using an equipment-based augmented reality interface.

Now that we have discussed both reality-based and augmented reality games, we conclude our discussion of the taxonomy with virtual world games.

2.1.6 Virtual World with Free-Motion Interface

Most video games are based on a virtual world. All of the objects, characters and environments exist inside a computer simulated environment. Conventional video games are played with gamepads or joysticks. These input devices are sufficient for providing input. However, games can become more physical by adding a free-motion interface. Free-motion interfaces allow players to use their entire body as an input device. Examples of games that use free-motion virtual world interfaces are in the
CHAPTER 2. BACKGROUND

4. Kick Ass Kung-Fu (figure 2.7) is a martial arts fighting game where players combat virtual opponents [40]. People play in a large open space with two screens on opposing sides. The game is projected on to these screens while a real-time image of the player is captured by a camera and placed in to the game. Every action performed in the real world is transferred into the virtual world. Physically walking, jumping, kicking and punching are all directly translated into the game, making this a free-motion interface. Although the player appears to be in the game, the image she sees is a virtual representation of herself. As a result, the game environment, player, and opponents are virtually represented.

In addition to being an interactive game, Kick Ass Kung-Fu is used as a training tool for martial artists. When training, practitioners must ensure they maintain
proper form when performing punches and kicks. This can be difficult to judge without the use of mirrors or video playback. The camera in Kick Ass Kung-Fu captures the player and generates a profile view. The generated profile provides real-time visual feedback, allowing players to judge their form. The use of computer vision allows martial artists to practice without wearing motion capture equipment.

Another example of a free-motion game is *Nautilus* (figure 2.8) [73]. Nautilus is a cooperative game where the goal is to free a trapped dolphin. The goal is achieved by navigating a diving bell to the bottom of a lake. Players control the diving bell by physically walking around a room. As players stamp their feet or flap their arms, the diving bell rises. They may also lower the bell by standing still or crouching. This detection is possible through the use of floor sensors which can sense varying degrees of pressure. The virtual world is projected on a large wall. Lighting and aquatic sounds increase the sense of immersion.
There are numerous other free-motion, virtual world interfaces. Breakout for Two is a competitive game where two players in different locations kick a physical soccer ball at a virtual set of blocks [56]. Nintendo’s Wii Sports includes activities such as baseball, which require players to physically swing a motion sensitive controller [19]. EyeToy games use a video camera to capture body movements as input for various mini-games [29]. Finally, Dance Dance Revolution is a dancing game where players step on pressure sensors in time with music [17].

An advantage of free-motion virtual world games is that players’ motions are not restricted. A disadvantage is capturing player motion is difficult. For instance, complex image recognition is required in Kick Ass Kung-Fu. Another example is that gesture recognition is difficult to program for in Wii Sports. However, the virtual game world allows players to be immersed in imaginative environments such as the bottom of a lake in Nautilus.

### 2.1.7 Virtual World with Equipment-Based Physical Interfaces

In *equipment-based virtual world interfaces*, players interact with an input device that requires significant physical exertion to operate. The game world exists entirely within a computer-simulated environment. Examples of games that use equipment-based virtual world interfaces are FlyGuy, Push’N’Pull, GameBike, and Exer-station (figure 2.1).

In the game *FlyGuy*, a hang gliding experience is simulated by strapping players into a harness [57]. The harness is attached to a metal frame, which acts as the interface. Players control an in-game avatar by twisting, turning, pushing and pulling
their bodies. Players view a screen that displays their avatar, other players, and the environment.

*GameBike* is a stationary bicycle that controls games on the PlayStation 2 console. Instead of using a traditional gamepad to control the game, players pedal the bicycle to provide input. *Virku* is a research project where users pedal through a virtual environment using a stationary bicycle [55]. The virtual environment is generated with map information, and affects pedaling effort. Resistance increases or decreases depending on the slope of the hill. The virtual world is projected on to a large screen where players are immersed in the environment. The game is played from a first-person perspective, so there is no avatar on screen.

*Push’N’Pull* is a resistance training game [57]. The goal is to capture particles in the virtual world with a shared sphere. To do this, players exert synchronized actions on a *Exer-station* [46] joystick to move the sphere. The joystick is a large vertical bar that players push or pull. Forces applied to the joystick are then translated into input for the game. The display is divided into two sections. One section displays the game world, while the other displays a live video feed of the other player. This allows the players to communicate with one another over a videoconference system.

A disadvantage of equipment-based virtual world interfaces is they are not easily accessible to the public. All of the games we discussed require user interfaces that are expensive, inflexible, and unportable. For instance, FlyGuy requires a costly custom frame to suspend players in midair. The frame can only be used for hang gliding games, making it inflexible. A dancing game, for instance, is incompatible with the frame. On the other hand, an advantage is that equipment-based virtual world interfaces may provide more vigorous exercise (eg. GameBike) than Wii Sports.
2.1.8 Virtual World with Traditional Electronic Interface

Traditional electronic virtual world interfaces use conventional input devices such as gamepads or keyboards to control actions in the game. This interface requires less physical exertion than equipment-based or free-motion interfaces. As mentioned earlier, Pacman is an example of a game where players view a virtual world while controlling their avatar with a joystick. Other examples of games that use traditional electronic virtual world interfaces are Human Pacman (helper), and Age Invaders (helper/opponent) (figure 2.1).

Thus far we have discussed games that take place in one type of game world and use one style of interface. Therefore such games inhabit a single box in the taxonomy of figure 2.1. However, it is possible for multiplayer games to provide different game
Figure 2.10: Age Invaders with Traditional Interface [45]

worlds and interfaces to different players depending on the players’ roles. *Human Pacman* [25] and *Age Invaders* [45] use both a traditional electronic virtual world and free-motion augmented reality interface depending on the player’s roles.

As mentioned earlier, in *Human Pacman*, players play a game of Pacman in the physical world. In addition to the physical players (ghosts, pacman), there are helpers (figure 2.9). Each pacman and ghost is paired with a helper. Helpers have a view of the entire playing field and the locations of other players via a virtual world map. Therefore it is the helpers’ task to relay this information to their partnered ghost or pacman.

Helpers use a traditional electronic virtual world interface to relay information between players. Since helpers are only required to view a map, they view the virtual world using a monitor. Messages are sent via a keyboard.

Recall that in the game Age Invaders, physical players shoot each other with
rockets while walking on a game board [45]. Similarly to Human Pacman, each physical player is partnered with a virtual player. Virtual players assist physical players by placing “powerups” in the game. Virtual players use a conventional desktop computer. This computer provides an abstracted view of the game board via a virtual world (figure 2.10). “Powerups” are placed into the virtual world using a traditional keyboard.

Virtual game worlds are typically displayed via traditional electronic virtual world interfaces. These games benefit from their simplicity and accessibility. For instance, the helper in Human Pacman does not require anything more than a keyboard to relay information to their partner. From a physical activity perspective, a major disadvantage of these games is their lack of physical exertion.

We have discussed several examples of exercise games. Kick Ass Kung Fu used a free-motion interface to provide a natural method for martial artists to perform their techniques. FlyGuy used an equipment-based interface to simulate hang gliding. Suspending players in mid air with a harness provided a great sense of immersion. We also looked at many game worlds. These ranged from the augmented reality of Age Invaders to the traditional virtual world of Pacman.

In some of these games, a specific game world and interface was chosen to maximize the sense of immersion. In Kick Ass Kung-Fu, the sense of immersion and enjoyment was so great that people forgot they were performing a physical activity. This increased immersion might motivate people to adhere to exercise using this game [79]. However, it would be unwise to assume immersion is a factor increasing exercise motivation without proper experimentation. Therefore research is required to determine whether embedding exercise in video games improves exercise motivation,
or what kinds of people might find exercise games appealing. The next section introduces the theory of engagement and its effect on users of interactive systems. This is followed by a thorough examination of research performed in the exercise motivation literature.

2.2 Engagement

Video games in general are designed to provide an enjoyable experience. However, we are also interested in the engagement that occurs between players and the exercise video games they are playing. Engagement is defined as a “state of mind that evokes a feeling” [47]. The most probable theory of engagement is Csikszentmihalyis theory of optimal engagement or flow. Flow theory is a state where people are so involved in an activity that nothing else appears to matter. The experience is so great that people will perform it even at great cost. The components of flow include enjoyment, intrinsic motivation, focused attention, and goal-directed activities. These components cause individuals to lose track of time and their sense of self during the experience [31].

O’Brien [59] proposed a process model of engagement involving three phases: point of engagement, engagement phase, and point of disengagement.

At the point of engagement, something eye catching or dynamic must happen for engagement to occur. For instance, a visually appealing interface or piece of text may interest users to begin operating a computer system. Such a system must engage users without overwhelming them so they may enter the engagement phase.

In the engagement phase, users’ attention moves beyond the initial attraction of the system into focusing on the task or content. During this phase, there is an interplay between cognitive goals, mental models, and motor skills to create engagement
The system must provide users with sufficient feedback and challenge to match his or her cognitive, motor, and affective needs, or else disengagement occurs. At the point of disengagement, users end their engagement with the system. Disengagement may occur because of positive factors (satisfying users’ needs), or negative factors (frustration, lack of/too much challenge or feedback, loss of interest/motivation, or perceived lack of control). Engaging systems should ensure all disengagements are positive.

The theory of engagement [47] and the process model of engagement [59] suggests that it is important to understand how to make systems engaging, how to measure that engagement, and how to know when users are engaged. It is possible that players of exercise video games may become so engaged that they forget they are exercising. It is important to understand and measure the engagement that occurs with these games. This information will help game developers create increasingly engaging exercise video games.

2.3 Exercise Motivation Literature

In the previous sections, we discussed numerous examples of exercise games. An underlying goal of some of these exercise games is to improve peoples’ motivation to adhere to exercise [79]. Motivation is defined as “the (conscious or unconscious) stimulus for action towards a desired goal” [61]. According to Wininger and Pargman, enjoyment is an important factor in motivating people to adhere to exercise programs [81]. The idea is that by combining the fun of games with physical activity, people will be more likely to exercise. The commercial success of Wii Sports and Dance Dance Revolution shows that this is true for some games and people. However, there has
been little attempt to analyze what makes a successful exercise game. Thankfully, there is a breadth of exercise motivation literature that examines factors that affect exercise motivation.

2.3.1 Framework

The *theory of planned behavior* attempts to understand human behavior (figure 2.11). According to the theory of planned behavior, human behavior is guided by three beliefs:

- **Behavioral beliefs.** The beliefs about the possible consequences of the behavior.
- **Normative beliefs.** The beliefs of behavioral expectations of others.
- **Control beliefs.** The beliefs about the presence of factors that may affect the performance of the behavior.

Collectively, the behavioral beliefs make the *attitude toward the behavior* favorable or unfavorable. Normative beliefs lead to perceived social pressure or *subjective norm*. Control beliefs lead to *perceived behavioral control*. The attitudes toward a behavior, subjective norm, and perceived behavioral control then lead to the *intention* to perform a *behavior*.

Generally, the greater the attitude and subjective norm, the greater the perceived control. This leads to a strong intention for a person to perform a behavior. People are then expected to carry out their intention when the opportunity occurs. Intention typically comes immediately prior to behavior. This makes intention a good predictor of behavior. However it is possible for perceived behavioral control to be a predictor for behavior (dashed line in figure 2.11).
To summarize, a behavior, such as exercising for thirty minutes daily, depends on a number of factors. These factors include a person’s belief of the expected outcomes of exercise, the social expectations for the person to exercise, and contributing/detracting factors that may affect the performance of exercise. These factors contribute to a second level of factors affecting the attitude (enjoyment/pleasure), social pressure (social influence), and belief in a person’s ability to exercise (self-efficacy). Together, these factors affect the person’s intention to perform exercise. The decision to exercise ultimately depends on the strength of the intention.

Rhodes et al. conducted a study examining this theory in relation to exercise. They found attitude (enjoyment, pleasure, excitement) significantly predicted exercise intention. They also found intention to be a predictor of exercise adherence [68]. Research by Emmons and Diener, Wankel, and Andrew et al. supported these findings as they found enjoyment to be an important predictor of exercise adherence [4, 35, 78].
In addition to enjoyment, preference of exercise was also linked to exercise adherence [13, 75, 33].

We introduced this framework to help readers understand how the following factors (attitude/enjoyment, subjective norm/social influences, perceived behavioral control/self-efficacy) in the exercise motivation literature come together. We begin our study of the literature by examining how exercise enjoyment is influenced by factors such as music, instructor, and exercise role-identity.

\subsection*{2.3.2 Music, Instructor, and Exercise Role-Identity}

A study by Wininger and Pargman [81] states that exercise adherence is heavily influenced by exercise enjoyment. However, little research has been conducted in order to determine the factors contributing to the enjoyment of physical activity. Based on past research and theory, they measured three factors that affect enjoyment in an aerobics dance class. These factors were satisfaction with the music in the exercise environment, satisfaction with the instructor, and salience of exercise role-identity.

Components of music can affect people's moods during exercise. Wales found that upbeat music significantly decreased feelings of anger, fatigue, and depression compared to slower music [77]. Lee provided further evidence that exercising to upbeat music during treadmill running led to significantly higher positive moods compared to slower music [49]. Steptoe and Cox also added that exercising to music reduced the perceived physical exertion [72]. Boutcher and Trenske [12] supported Steptoe and Cox by providing further explanations for this effect. They state that music may act as a distracter to physical discomfort. Additionally, music may lead to
positive states due to its content or because of its association with past experiences.

The second factor is the instructor and her ability to properly motivate her students. Patton found an instructor’s enthusiasm and support were more important in determining exercise enjoyment than music preference. Westcott’s study supported this by determining four characteristics that participants deemed most important when choosing a fitness instructor[80]. These factors were an instructor’s knowledge of physical fitness, teaching skills, enthusiasm and personal attention given to participants.

The final factor is role-identity. Role identities are defined as the components of the self that correspond to the social roles we play [39]. Salience of role-identity is the degree to which someone defines themselves in a particular role-identity. For instance, the higher the salience for an exercise role-identity, the more likely someone defines themselves as an exerciser. Such an individual would then enjoy and spend more time engaged in exercise [21]. Exercise role-identity is a variable that affects exercise enjoyment. A study by Curry and Weaner reported a strong positive correlation between the salience of sport identity and enjoyment of sports participation [32].

To test the effectiveness of music, the instructor, and exercise role-identity on exercise enjoyment, the experimenters set up aerobics classes twice a week. Classes were taught by certified aerobics instructors, all of whom were female. A total of 282 female volunteers were recruited. Each class held between 60-75 participants. Ten to fifteen minutes prior to the aerobics class, the participants were asked to fill out a survey. This survey measured satisfaction with the music, instructor, and salience of exercise role-identity.

The results showed significant correlations between satisfaction of the factors and
enjoyment of the exercise. Music was the best predictor of exercise enjoyment followed by instructor and exercise role-identity. The authors conclude that exercise instructors can maximize exercise enjoyment by first focusing on the music, specifically the tempo and beat. Feedback about music satisfaction should be obtained from the participants and adjusted accordingly. Positive reinforcement and encouragement were identified as important characteristics of instructors. Therefore instructors should consciously encourage and praise their participants. Exercise role-identity cannot be directly affected by the instructor. However, providing an enjoyable experience for participants will likely increase their salience of exercise role-identity over time.

2.3.3 Peer Support

Support in the form of encouragement improves exercise motivation. However the benefits of support extend beyond having a good instructor. Hohepa et al. suggest that peer and familial support can also assist in encouraging people to exercise [41]. In the study, high school students were interviewed to determine what they perceive as barriers to physical activity. Identified barriers included a lack of peer social support and feeling perceived incompetence. In addition to identifying barriers, students also provided suggestions to improve their willingness to participate in physical activities.

A lack of peer social support was identified as a key barrier. Specifically, students refused to be active because they either lacked friends, or existing friends were unwilling to be active. Students were also pressured by friends to participate in sedentary activities. Another barrier to physical activity was students’ self-perception of incompetence as compared to their peers. Students feared being mocked by superior players. Also, if students felt their own skills were inadequate, they did not wish to
let down their team.

Solutions provided by students to improve sports participation differed between females and males. For females, having a friend join a team eliminated barriers related to lack of support. By having a friend on the same team, players can support each other through encouragement, and guidance. To a lesser extent, parents can also encourage their children to participate in physical activities. In particular, males indicated their parents could push them to be more active. Parents can also be supportive by providing transportation to activity locations and limiting the amount of time devoted to sedentary activities.

By eliminating barriers, people are more likely to exercise in groups. Students identified fun, achievement, and health benefits as the perceived benefits of physical activity. Another benefit of grouping is increased exercise adherence.

A study by Beauchamp et al. looked at older adults’ adherence for exercising alone versus in groups [9]. The study was performed to understand why older adults exercised alone instead of in groups. Beauchamp et al. determined that the alternative to exercising alone was to exercise in groups with people of dissimilar ages. They conclude that older adults have a general preference for exercising in age-matched group based-settings and that adherence is superior in groups compared to exercising alone.

### 2.3.4 Self-Efficacy

Self-efficacy is defined as the “belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations” [7]. In other words, self-efficacy is the belief in a person’s ability to overcome difficulty. Efficacy beliefs affect
goals and outcomes. The higher someone’s self-efficacy, the higher they will set their goals and the more committed they will be to achieving them. They also expect their efforts in completing their goals to yield positive outcomes. This is in contrast to people with low self-efficacy who set low goals and expect poor outcomes as a result of their efforts. Self-efficacy also affects how people deal with difficult situations. People with low self-efficacy are easily intimidated and quickly give up when faced with difficulty. On the other hand, those with high self-efficacy view difficulties as surmountable challenges and are willing to tackle them [8].

In order to increase self-efficacy, short and long-term goals should be introduced. Long-term goals provide a point of focus for someone to aim for. However, long-term goals do not take someone’s present self-efficacy into account. Therefore short-term attainable goals help people succeed with simple tasks. As they accomplish these tasks, their self-efficacy increases, providing them with the confidence to overcome more difficult challenges.

As an example of the effects of exercise self-efficacy, Mitchell et al. looked at how self-efficacy can affect the dropout rate from obesity treatment [54]. High dropout rates pose a major problem. In addition to losing help from the treatment programs, participants lose motivation to control their weight. They may perceive their lack of success as personal inadequacies rather than faults of the program.

The authors hypothesize that self-efficacy may be one factor in explaining why participants drop out. Dropouts from obesity treatment failed to perceive themselves as successful because they were convinced they would not succeed. This suggests low weight control self-efficacy. As a result, dropping out seems more appealing than failing to succeed in losing weight.
The study looked at 414 women registered in a Weight Watchers program. Weekly telephone calls were made to the participants during the 12 week program. They were asked questions about their demographic characteristics, weight loss, intention to continue or dropout, attendance, and weight loss self-efficacy.

During the 12 weeks, 101 out of the 414 women dropped out despite losing a similar amount of weight to participants who stayed. As a measure of weight control self-efficacy, participants were asked to rate their confidence that they would achieve their goal weight. Every week, those who dropped out reported less confidence that they would achieve their goal weight. Participants were also asked if they felt successful in regards to their weight loss and eating habits. They were given a score based on their responses. Lower scores corresponded to lower feelings of success. Dropouts reported lower scores than those who stayed.

The authors concluded that at the beginning of treatment, self-efficacy is an important predictor of the decision to drop out of a weight control program. Participants who eventually dropped out began with a lower expectation of success, which is met when they drop out several weeks later. Additionally, perception of success was more important than actual success when determining drop out rates. Weight loss rates did not affect drop out rates. This suggests that dropouts fail to perceive themselves as successful because they are convinced they will fail, even with successful weight loss.

2.4 Conclusion

In this chapter, we looked at many examples of exercise games. We have seen how they are represented to the user via different styles of game world. We have also
seen how changing the user interface produces different levels of physical exertion. In addition to examining exercise games, we are interested in motivating people to exercise in games. Before we can understand how to improve exercise motivation in games, we had to understand people’s engagement with interactive systems and how to motivate people to exercise in general. We introduced the theory of planned behavior to provide a framework of how our discussion of the exercise motivation literature comes together. In the literature, we examined five factors: music, instructor, exercise role-identity, peer support, and self efficacy that affect exercise motivation through proxies such as enjoyment. These factors have been demonstrated to affect people’s motivation to exercise in the exercise domain. Although their use in domains outside of exercise is unknown, we wish to apply knowledge of these factors to the design of exercise video games. The following chapter will introduce game requirements derived from the exercise motivation literature. These game requirements were used as a basis for two exercise games that we created.
Chapter 3

Game Requirements

As with any software, games must be created to meet specific design requirements. These requirements vary depending on the goals of the game. If the goal for a horror game is to frighten players, the game should have immersive graphics and eerie sound. The requirements of an exercise game, must address its goal of motivating people to exercise. While there has been some early research proposing design requirements for exercise games [27], there has been little focus on how game requirements can be drawn from the exercise motivation literature.

As we have seen in our discussion of the exercise motivation literature, there has been considerable research on the factors that affect exercise motivation. We hope that these motivational factors can be captured in exercise games. We have drawn from the factors that affect motivation to propose a set of game requirements (table 3.1)

These game requirements are propositions based on our examination of the exercise motivation literature. Through our examination of the game requirements, we will present examples of traditional video games. Using these games, we illustrate
Figure 3.1: List of Game Requirements and each factor the requirement supports the pitfalls that exist if mechanics from traditional games are naively applied to exercise games. Although some of these requirements may seem straightforward, much research is required to validate their effectiveness. In chapter 4, we experimentally investigate a subset of these requirements.

We have implemented two exercise games to illustrate how well these requirements can be translated to actual game designs. The first game, Life is a Village, addresses requirements dealing with sustained long term exercise. The second game, Frozen Treasure Hunter, looks at the effectiveness of exercise in a collaborative setting. As shown in table 3.1, we have identified several game requirements. Depending on the game, these requirements may be applied to the design of single-player games, multiplayer games or both.

We begin our discussion of the requirements with our pre-existing game, Life is a Village. Life is a Village is a collaborative project developed by many people since

<table>
<thead>
<tr>
<th>Game Requirement</th>
<th>Exercise Motivation Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game should not reveal players’ fitness level</td>
<td>Self-Efficacy (People with low self-efficacy easily intimidated)</td>
</tr>
<tr>
<td>Game should provide achievable short/long term goals</td>
<td>Self-Efficacy (Methods to increase self-efficacy)</td>
</tr>
<tr>
<td>Game should integrate music</td>
<td>Music (Increases positive moods)</td>
</tr>
<tr>
<td>Game should provide leadership for novice players</td>
<td>Instructor (Guidance and support)</td>
</tr>
<tr>
<td>Game should assist players in forming groups</td>
<td>Peer Support (Increase exercise adherence)</td>
</tr>
<tr>
<td>Game should remove barriers to grouping</td>
<td>Peer Support, difference in skill/fitness level (Eliminates barriers to grouping)</td>
</tr>
</tbody>
</table>
3.1 Life is a Village

*Life is a Village* (figure 3.2) is an exercise video game that takes place in a virtual world. It uses an equipment-based physical interface to provide input. The virtual world is presented via a large screen wall display using a Boxlight DLP projector [28]. The player controls a virtual avatar by pedaling a Tunturi E6R recumbent bicycle [76] while steering with a wireless Logitech gamepad [50]. Controlling the bicycle is similar to cycling in the physical world. Pedaling harder increases the avatar’s speed, and cycling uphill is more difficult than cycling downhill. Players may adjust the bicycle’s virtual gear by trading off higher tension on the pedals for faster speed.
A recumbent bicycle was chosen as opposed to a traditional bicycle because of its increased stability and comfort. An additional benefit is that cycling is a low-impact exercise with a low risk of injury. Players can easily take breaks simply by stopping pedaling. Therefore people who are overweight or unused to exercise may find it more approachable.

The core goal of the game is to build a village. This is a long-term goal that requires many hours of play over multiple play sessions. To create buildings for the village, the player must gather resources. For instance, a town hall requires wood and stone. To gather a resource, players first find the resource by cycling to a marked resource node. Upon discovering a resource node, players press a button on the gamepad to dispatch villagers to harvest the resource. As soon as the villagers have harvested the necessary resources, players can construct new buildings. Resources required for simple buildings are easily available nearby. These resources can be discovered with minimal cycling. However, rare resources that allow for the creation of more advanced buildings are more difficult to find. These resources require players to cycle great distances or climb steep mountains to acquire. This provides players with easily achievable initial goals, as well as longer term goals that can only be achieved when their fitness level improves.

Development of Life is a Village is a continuing and collaborative project. It has been developed by many people over the years. The core game was developed by Will Roberts. Rob Fletcher and Banani Roy implemented the resource system and villager behavior. Irina Skvortsova provided much of the original art assets. Students of ARTF 338, Time-Based Media, contributed additional art assets. Students of CISC 864, Video Game Development, created systems in the game that allowed for easy
building creation, sound, natural weather, and quest systems. My contribution was in the creation of a quest system, in collaboration with Eric Qiu. The quest system allows players to speak to villagers to receive tasks. Upon completing tasks, players are rewarded with new buildings to construct.

The purpose of Life is a Village is to provide an exercise game that supports long term sustained exercise. In order for players to feel motivated to play the game, we have used game requirements derived from factors in the exercise motivation literature. We will discuss how these game requirements have been implemented into Life is a Village via specific game features. The exercise motivation literature will also be used to support our reasons for choosing each game requirement.

### 3.1.1 Game should hide players’ fitness level

The first requirement, hide player’s fitness level, is based on Bandura’s research on self-efficacy. From his research, people with low self-efficacy are easily intimidated when faced with difficulty [8]. They are easily convinced of the futility of their actions. Often, they will quit or avoid the problem rather than attempt to overcome it. People with low self-efficacy require guidance and encouragement to overcome their difficulties.

Ideally, people should be in an environment where they feel confident and comfortable. However this is difficult for people who begin an exercise program. For instance, a skinny person may feel intimidated in a weight room. Fear of judgment based on his appearance may be sufficiently de-motivating to cause him to quit.

Games have the potential to help in these situations. However, some traditional game mechanics may worsen these situations. For instance, in Warcraft 3 [15], players
CHAPTER 3. GAME REQUIREMENTS

compete against each other. Practice is important and new players may face weeks or months of defeats before they win their first game. New players may be ridiculed as “newbs” until their skills improve. In exercise games, a similar design choice would be to link performance to fitness. This approach may intimidate players in a competitive atmosphere. Unfit players will suffer de-motivating experiences as they consistently lose until their fitness improves.

Other games reward progress by reflecting a player’s achievements in her avatar through fancier armor or weapons. This design can be carried over to exercise games by showing an avatar becoming progressively fitter over time. This approach could negatively affect motivation as it recreates the discouraging atmosphere of being an unfit person at the gym.

To avoid creating an atmosphere where players can be judged based on their appearance, a player’s avatar can be masked. In Life is a Village, all players control a generic avatar which does not reveal their physical fitness. This allows players to play the game at their own pace without the fear of judgment from their peers. It could be argued that a player’s fitness level can be determined based on an avatar’s speed. However, it is impossible to tell whether a slow moving avatar is an athlete taking a leisurely stroll, or an unfit player cycling intensely.

3.1.2 Game should integrate music

Music is an important motivational factor in exercise. Wininger et al. performed a study of three factors influencing enjoyment of exercise: music, satisfaction with the instructor, and exercise role-identity [81]. The study concluded that music was the most important of the three. Wales found that upbeat music significantly decreased
feelings of anger, fatigue and depression compared to slower music [77]. Lee supported Wales by determining that exercising to upbeat music led to higher positive mood states compared to slower music [49].

People not only feel fewer negative emotions when exercising to music, but the exercise appears easier to perform. Steptoe and Cox, [72] and Boutcher and Trenske [12] discovered that people report a lower level of physical exertion when exercising to music versus exercising to a metronome or no music at all.

The evidence suggests that to enhance enjoyment, an exercise game should have music that is upbeat. Upbeat music may not be suitable for all games. Therefore Boutcher and Trenske state that music chosen by the exerciser, or in the case of games, the game player, may have the most positive effects.

Based on the music research stating the benefits of upbeat music, Life is a Village uses an upbeat jungle beat as background music. As mentioned before, upbeat music may not be appropriate all the time. Therefore the music can adapt to situations in the game. Calm music may play during exploration, while jungle beats play when players struggle to climb a mountain. The game expands the definition of music to include appropriate sound effects for events in the game. For instance, comical sounds play as items are collected, rain is heard when there is a downpour, and elephants trumpet when they appear.

3.1.3 Game should provide achievable short and long term goals

Integrating short and long term goals will help people with low self-efficacy. Self-efficacy affects a person’s outlook, aspirations, and belief in their ability to complete
goals, such as exercise goals [8]. People with high self-efficacy are motivated and believe they can overcome adversity. They see barriers as a challenge and expect the outcomes of their actions to yield positive results. Those with low self-efficacy expect their outcomes to result in failure. Therefore when faced with a challenge, they may quit before trying.

Low self-efficacy is therefore a barrier to beginning and continuing an exercise program. Unfit people quickly see the enormity of the challenge of achieving a fitness goal, such as reaching a goal weight. Unfit people with low self-efficacy will quit an exercise program since they expect to fail in achieving their fitness goals.

A study was performed by Mitchell et al. to look at the effects of self-efficacy in a Weight Watchers program [54]. They found that 75 percent of dropouts from the program had been identified with low self-efficacy, while 2/3 of those who remained had high self-efficacy. Participants who dropped out experienced similar weight loss as those who continued. This suggests that dropouts from obesity treatment failed to perceive themselves as successful because they were convinced they would not succeed.

Bandura suggests that to increase self-efficacy, people should maintain both short and long-term goals. Long-term goals provide a general guideline for people to follow. Short-term goals are specific tasks that people must complete in order to achieve their long-term goals. Completing short-term goals will increase self-efficacy, enabling people with low self-efficacy to complete more difficult tasks.

This approach is present in exercise programs that encourage the creation of short and long-term exercise goals. Similar to Bandura’s suggestion, short-term goals that can be readily achieved allow participants to feel an immediate sense of progression.
and achievement. Attaining short-term success, such as progressing from 10 minutes of cycling to 15 minutes, breaks up long-term goals into manageable steps.

Life is a Village takes short and long-term goals into consideration through a number of in-game activities. The core long-term goal is to build a village. To do so, players must search the world for resources which allow them to construct new buildings. As buildings are constructed, resources are consumed, forcing players to travel further in search of new resources. By completing short-term goals such as collecting nearby resources, players become accustomed to the game while improving their fitness.

3.1.4 Game should facilitate leadership for novice players

Beginning an exercise program is difficult. Therefore, people cite the importance of a good instructor in the enjoyment of their programs. Games should therefore provide leadership for novice players. Wininger et al. found instructors to be the second most important factor in participants’ enjoyment of an aerobics class (after music). Instructors were an important factor because of their knowledge of fitness and encouragement of participants [81]. Westcott conducted a study looking at the most important characteristics of fitness instructors [80]. Health club members ranked an instructor’s knowledge of fitness as the most important characteristic. This was followed by the instructor’s teaching skill, enthusiasm, and amount of personal attention received. Games should facilitate leadership of players, particularly novice players. The leaders should provide their knowledge of fitness, and encouragement to continue, in structured sessions.

Leadership in games can be provided similarly to real life exercise classes. Group
leaders, whether they are experienced players or paid instructors, can help novice players learn basic skills and develop workout strategies. Existing multiplayer games already support leadership roles through clans. Specifically in Neverwinter Nights [14], “dungeon masters” act as an instructor by guiding groups of players. Another example is an online game Earth and Beyond [20]. Experience points are rewarded to advanced players who provide galaxy tours to new players in the game. The enjoyment of the experience for novice players can be greatly enhanced with a knowledgeable and supportive leader. A game that supports such a leader must have a mechanism to designate qualified group leaders.

We have discussed the potential benefits of having a human instructor in games. However, human instructors may not be available all the time. In these cases, artificial intelligence characters can take their place. These characters, known as non-player characters (NPCs), can provide guidance in the absence of a real instructor. This can be done directly by providing an NPC leader, or indirectly through quests to guide players.

Life is a Village uses both NPCs and quests to provide leadership for players in the world. Arrows point new players to areas of interest. When players begin the game, an arrow immediately points players to an NPC. Upon approaching the NPC, players are greeted and given a quest to complete. On-screen prompts and messages constantly inform players of their status and the objectives at hand. As a result, players are never at a loss of what to do.

We have seen how much of the exercise motivation literature can be translated into corresponding game requirements. Thus far, our focus has been on the single-player experience of Life is a Village. We have explained how these game requirements
may help to create a more motivating experience. Where relevant, many of these requirements also expand to multiplayer exercise games. In the previous chapter, we discussed literature that suggests exercise motivation can be enhanced in a group setting. The following section introduces Frozen Treasure Hunter. I developed this multiplayer exercise game with game requirements derived from literature examining collaborative exercise.

3.2 Frozen Treasure Hunter

Frozen Treasure Hunter (figure 3.3) is a cooperative multiplayer exercise video game focusing on collaborative exercise. The game takes place in a virtual world using an equipment-based physical interface. The virtual world is presented via a large screen...
wall display using a Boxlight DLP projector. Two players share control over a virtual avatar by performing two independent tasks.

One player acts as the *cyclist* by controlling the movement and steering of the avatar. Players move the avatar by pedaling a Tunturi E6R recumbent bicycle. Steering is controlled via a wireless Logitech gamepad. The bicycle controls are the same as those of Life is a Village. Cycling harder increases movement speed, and changes in terrain affect the bicycle tension. A recumbent bicycle was chosen over a traditional bicycle for its stability and comfort. Cycling also benefits from being a low-impact exercise, resulting in a lower risk of injury. Breaks are easily taken simply by stopping pedaling.

The second player acts as the *swatter* by controlling the avatar’s defensive capabilities. This is performed by swinging a Wii Remote and Nunchuk [26]. The Wii Remote and Nunchuk are two handheld input devices with accelerometers capable of detecting six degrees of freedom. Therefore, physical motion performed with these devices can be interpreted as input. Generally, the Wii Remote is held in the dominant hand while the Nunchuk attachment is held in the other. Frozen Treasure Hunter assumes the right hand is dominant. In the game, enemies throw snowballs at the players. To defend against the snowballs, the avatar can cast a spell to swat away these snowballs. Swinging the Wii Remote with the right hand deflects snowballs entering the right side of the screen. Similarly, swinging the Nunchuk with the left hand deflects snowballs entering from the left side of the screen. Since the players have complementary roles, people with radically different fitness levels can play together.

The goal of the game is to collect treasure scattered throughout the environment within a time limit. Enemies prevent players from completing their task. These
enemies defend the treasure by throwing snowballs at the players when they are within range. Being hit by a snowball stuns the players and impairs their vision, slowing down the collection. Players can defend themselves by swatting away the snowballs. Successfully swatting a snowball back will cause the villager to sleep for a few seconds. During this time, enemies will not attack and players are free to collect the treasure.

Upon collecting all of the treasure, players are given the choice of upgrading their speed or defensive capabilities. Upgrading speed allows players to move faster, while upgrading defense causes villagers to sleep longer when snowballs are swatted. Both players must vote and agree on a single choice. Once their selection is made, the upgrade is applied and a new set of treasure must be collected.

Players must cooperate to effectively collect the treasure. An excellent cyclist cannot collect treasure without a swatter as the cyclist would be constantly stunned by snowballs. Similarly, an excellent swatter can not achieve their goal without a cyclist to move them to the treasure. Additionally, swatting stops all movement. Therefore swatting too aggressively prevents the team from moving even when the cyclist is cycling. However, failing to swat snowballs also stops movement as players are stunned.

Frozen Treasure Hunter is a cooperative multiplayer exercise game used to examine the effects of collaborative exercise on exercise motivation. The exercise motivation literature suggests that there are beneficial effects when exercising in groups. We now discuss this research in detail and explain how it has been translated to game requirements, which in turn have been applied to the designed Frozen Treasure Hunter.
3.2.1 Game should remove barriers to grouping

In a study performed by Hohepa et al., students from a New Zealand high school were interviewed about their views on participating in physical activity [41]. The students listed barriers to physical activity such as a lack of peer support, perceived incompetence, and pressure to participate in sedentary activities. Students perceived themselves as incompetent in a number of ways. New students participating in sports felt de-motivated when skilled students flaunted their skills. New students also doubted their own skills, fearing they would let down their team. As a result of the perceived incompetence, students had disincentives to begin or continue their physical activity. This is consistent with studies by Wininger et al. [81] and Bandura [8], who relate low exercise self-efficacy to unwillingness to perform exercise. Games should also remove barriers to encourage grouping.

Online multiplayer games commonly introduce artificial barriers preventing players from grouping. These barriers are introduced when players play on different servers, teams, or levels. Differences in level are analogous to players of different skill level in sports. For instance a level 50 player in World of Warcraft [16] cannot effectively group with a level 1 player as the powerful enemies fought by higher level players would crush new players. Exercise games should avoid leveling systems that can result in similar barriers.

The fitness barrier is unique to exercise games. Peoples’ fitness levels can vary drastically. When playing multiplayer exercise games, there must be some mechanism to allow people of different fitness levels to play together. Without it, exercise games will always favor fit players. For example, GameBike uses a bicycle to control the speed of a player’s car in a racing game [34]. Fit players will always defeat unfit
players because they can pedal harder and faster. Instead, biometric feedback from players’ heart rate might be used to scale the car’s speed, where players’ increase in heart rate reduces the tension on the bicycle. This would allow an unfit player to remain competitive with an athlete as long as she is working hard relative to her fitness level.

Frozen Treasure Hunter eliminates fitness barriers by assigning players separate complementary tasks. One player drives, while the other player swats. By separating these activities, one player’s ability to perform his task does not directly affect the other player’s ability to perform her task. For instance, the cyclist’s pedaling rate does not affect the swatter’s ability to defend. This is in contrast to a real world situation where two joggers of different fitness levels must accommodate one another. Either the fit jogger slows down for the unfit partner, or they don’t jog at all.

3.2.2 Game should actively assist players in forming groups

As mentioned in the previous section, Hohepa et al. showed lack of peer support as a key barrier to physical activity. High school students avoided physical activity because of their friends’ unwillingness to exercise. Additionally, there was peer expectation to participate in sedentary social activities. Students who failed to join in sedentary activities were deemed antisocial. When friends are not available, students feel less inclined to exercise. To eliminate this peer-influenced barrier to exercise, exercise games must provide mechanisms to help participants find others to play with. This will foster a sense of community, allowing friends who are interested in exercise to easily join.

Perhaps more important than simply encouraging people to begin exercise is to
actively assist them in continuing to exercise. A study by Beauchamp et al. conclude that as long as individuals exercise in age-matched group-based settings, then adherence is superior in groups compared to exercising alone [9]. Due to the benefits of grouping, games should actively assist players in forming groups.

Existing online games have mechanisms supporting grouping. Many games provide activities that require more than one player to complete. *Guild* allow small communities of players who get together and play under an associated name. These grouping mechanisms should be as simple as possible. Players should be able to join together quickly without traveling long distances. There should be facilities for easily finding other players who are looking for company. There should also be easy ways of communicating with friends outside of the game, allowing players to arrange specific times to play together.

Frozen Treasure Hunter actively assists players in forming groups by providing a cooperative game where grouping is crucial to the game play experience. Both players control a single avatar where each player is assigned a unique task. Individually, they can not complete their goal of collecting treasure. A cyclist will be constantly stunned by snowballs without the aid of a swatter. The swatter would not be able to move to the treasure without a competent cyclist. As a result, each player must rely on the other for them to complete their goal successfully. This provides a sense of camaraderie where each player realizes their own importance and that they are an integral part of the team.

We concluded our discussion of the sports psychology literature by focusing on research examining the benefits of group exercise. Benefits of grouping include increased exercise participation through peer support and increased exercise adherence.
To achieve these benefits, the multiplayer requirements focus on encouraging grouping and eliminating barriers to grouping. We created the multiplayer exercise game, Frozen Treasure Hunter using these game requirements. Although we have covered many game requirements using both Life is a Village and Frozen Treasure Hunter, the focus of this research is on collaborative exercise games.

3.3 Conclusion

In this chapter, we proposed a list of game requirements inspired by motivational factors in the exercise literature. We identified pitfalls in using game mechanics of traditional games in exercise games. We also introduced our two exercise games, Life is a Village and Frozen Treasure Hunter. Using these games, we illustrated how our requirements can be applied to exercise games. In the next chapter, we use our game, Frozen Treasure Hunter, to determine whether players prefer multiplayer over single-player exercise video games.
Chapter 4

Experiment

In the previous chapters, we have discussed examples of how it is possible to embed exercise into games. There has been some research examining properties of exercise video games such as exercise adherence [79]. However, there has been little research attempting to understand the effects of group exercise in exercise games on exercise enjoyment and engagement.

Studies by Beauchamp [9] and Hohepa [41] have shown group exercise to increase exercise participation and adherence [41, 9]. These studies address traditional exercise such as sports, played in a co-located setting. There is also evidence that suggests enjoyment [78, 35, 4] and preference [13, 75, 33] of exercise is a predictor of exercise adherence. These results raise the question of whether the benefits of exercise enjoyment occur with multiplayer exercise games, and in particular whether these benefits carry over to exercise games played over a network. It’s possible that enjoyable exercise video games may increase exercise participation and adherence. However longitudinal studies will be required to determine if this is true.

If the motivational benefits of exercise do carry over, we are also interested to see
if peoples’ self-efficacy is a factor in their enjoyment of exercise games. An underlying problem of traditional exercise is that people with low exercise self-efficacy have difficulty achieving exercise goals [69]. We hypothesize that this is not true with exercise games. Even when video games have an exercise component, people with low exercise self-efficacy view them as less intimidating than traditional exercise.

We performed two experiments to address three questions about collaborative multiplayer exercise games

- Do the benefits of exercise enjoyment and engagement occur with exercise video games?
- Do players prefer co-located or distributed multiplayer games?
- Do exercisers and non-exercisers enjoy exercise games?

The first question is whether the benefits of grouping translate to exercise games. Our first experiment addresses this issue by gauging players’ enjoyment and engagement after they played a multiplayer version of Frozen Treasure Hunter. Players’ engagement and enjoyment was then compared to their experience with a single-player version of the game.

Results from the first experiment revealed that players preferred multiplayer play. Our second question is whether players have a preference of co-located or distributed multiplayer play. Experiment two addressed this issue by measuring players’ enjoyment and engagement after having played co-located and distributed versions of Frozen Treasure Hunter.

The final question is what kinds of people (low or high exercise self-efficacy) enjoy exercise video games. Experiment two also addressed this issue by measuring players’
exercise self-efficacy and feelings of support when playing team sports before playing the co-located and distributed versions of Frozen Treasure Hunter.

We used our game, Frozen Treasure Hunter, to perform our experiments. Each experiment had two conditions. In the first experiment, players played multiplayer and single-player versions of the game. Participants played as the cyclist while actors played as the swatter. In the second experiment, players play the game in a distributed and co-located setting. Once again, participants play the cyclist while actors played as the swatter. Questionnaires were filled out to gauge players’ enjoyment, engagement, self-efficacy, and team sports participation.

The following sections will detail our hypotheses, experimental apparatus, measures, and use of actors. We will then provide a detailed explanation of both experiments. Following our experiments, we determined that participants preferred the multiplayer version of Frozen Treasure Hunter. Additionally, we found no correlation between self-efficacy and peoples’ preference of co-located versus distributed play. We will conclude this chapter with a discussion of what these results mean for game designers.

4.1 Hypotheses

Experiments performed with Frozen Treasure Hunter addressed three hypotheses about collaborative exercise games. These three hypotheses are: people find collaborative exercise games more enjoyable and engaging than single-player exercise games; distributed group exercise is just as enjoyable and engaging as co-located group exercise; and people who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers. We present these hypotheses and their
rationale below.

People find collaborative exercise games more enjoyable and engaging than single-player exercise games. In chapter 2, we provided examples of how it is possible to embed exercise into games, sometimes with significant commercial success. Studies by Graves et al. [37] and Warburton et al. [79] have shown the effectiveness of single-player exercise games. However, there has been little research attempting to understand the effectiveness of grouping in exercise video games.

Distributed group exercise is just as enjoyable and engaging as co-located group exercise. Traditional sports such as basketball or soccer are played in a co-located setting where players are in the same location. However, with online games, players play together even though they are physically distributed in many locations. Unlike traditional sports, exercise video games combine the co-located play of traditional physical activity with the distributed play of online games. Therefore it is unclear if there is a preference between the two settings.

People who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers. “People of low-efficacy are easily convinced of the futility of effort in the face of difficulties. They quickly give up trying” [8]. This suggests people with low exercise self-efficacy are easily intimidated. They see achieving exercise goals as insurmountable obstacles. As a result, they do not enjoy exercise. They may even find exercise games unappealing.

“Those of high efficacy view impediments as surmountable by improvement of self-management skills and perseverant effort” [8]. This suggests people with high exercise self-efficacy are confident in their ability to performing exercise. They are accustomed to traditional exercise and do not require games to motivate them to
These exercise. Group exercise games may not benefit them.

4.2 Overview of Experiment

We performed two experiments to test our hypotheses. Experiment one tested our first hypothesis. Experiment two tested both the second and third hypotheses. The experiments used the same apparatus, measures and general methodology.

The target audience for this research is sedentary individuals (non-exercisers) who are familiar with and enjoy playing video games. A range of people with varying physical activity levels were recruited. This allowed us to compare questionnaire scores of our exercise video game amongst a diverse population. Participants were recruited through email notices and posters distributed around the university campus. Recruitment notices stated that participants must:

- Be age 17 and up.
- Have some experience in the past playing a computer game.
- Be able to perform light exercise on a recumbent bicycle.
- Have no physical conditions which may contraindicate light exercise.

Informed consent was obtained by all the participants at the beginning of the experiment. Participants were compensated with a ten dollar movie gift card for their time. Different participants were recruited for both experiments. Ordering effects were minimized by randomly assigning participants to each condition. I acted as the experimenter, leading participants through the experiments. The General Research Ethics Board approved the study protocol.
One hour was allotted for the experiment. Participants played the games in three, five minute sessions, totaling fifteen minutes of play during the experiment. The rest of the allotted time was devoted to filling out questionnaires and describing the experiment. One tutorial session was provided at the beginning to familiarize players with the game. Participants then played the game under two separate experimental conditions.
4.2.1 Experimental Apparatus

Experiments were performed using two rooms: a main room and a distributed room. Depending on the experimental conditions, either just the main room, or both rooms were used simultaneously. Equipment used primarily by the cyclist was placed in the main room. This room also contained the computer running the game. During co-located play, both players shared audio and visual equipment in the main room (figure 4.1).

Swatters were located in the distributed room during distributed play (figure 4.2). They were provided with a monitor and headset to view and listen to the game. Skype was set up with a computer in the distributed room. This allowed players in the distributed and main room to communicate.

The following sections highlight the specific apparatus used during the experiment.
CHAPTER 4. EXPERIMENT

Input

The cyclist provided input via a Tunturi E6R recumbent bicycle [76] and wireless Logitech gamepad [50]. The bicycle was connected to the main computer with a serial cable. The Logitech gamepad was connected via a wireless receiver.

The swatter used a Wii Remote and Nunchuk connected to the main computer via Bluetooth [26]. The Wii Remote and Nunchuk are equipped with accelerometers. This allows the controllers to interpret acceleration data as usable input. The controllers communicate via Bluetooth; therefore, the signals were accepted using a Bluesoleil Bluetooth adapter [10]. GlovePie scripts were used to interpret data from the controllers into useable game input [44]. Distributed players communicated via a wired microphone (main room) and headset microphone (distributed room).

Output

A BoxLight DLP projector was used to display the game on a large pull down screen in the main room. For distributed play, the player in a separate room viewed the game via a LCD monitor. This monitor was connected to the game computer via a long video cable. 5.1 surround sound speakers were used in the main room. Players in the distributed room used headphones.

4.2.2 Measures

We used questionnaires to measure players’ enjoyment, engagement, self-efficacy and team sports participation. Questionnaires were administered to the participants before the experiment, after each of the experimental conditions, and at the end of the experiment. Here we describe the questionnaires used, where they came from, and
what they attempt to measure. Cronbach’s alpha coefficients of internal consistency are presented in brackets. The alpha coefficient estimates how well a set of items can be used to measure a single variable [30].

Exercise Self-Efficacy Questionnaire

This questionnaire assesses people’s confidence in exercising when obstacles get in the way [52]. Obstacles are categorized as negative effect (.85), excuse making (.83), need to exercise alone (.87), inconvenience (.77), resistance from others (.85), and bad weather (.84). This questionnaire measures solely exercise self-efficacy, not exercise self-efficacy in the context of exercise video games. The questionnaire contains 18 questions on a seven point Likert scale.

Engagement Scale Questionnaire

The engagement scale measures usability (.87), attention (.94), aesthetics (.91), endurability involvement (.90), and novelty (.72) [58]. A statement about the game is presented and players are asked about their level of agreement. In total there are 31 questions on a seven point Likert scale. The scale was divided into two questionnaires. Attention and endurability questions were asked post-task; usability, aesthetics, and novelty were asked post-session. Note the alpha values for this questionnaire were calculated with our relatively small population (n=30).

Positive Team Sports Involvement Questionnaire

This determines how comfortable people are when playing team sports [11]. Questions are categorized based on competence and skill development (.87), and feelings of social
support and belonging (.74). This questionnaire was used to determine if there was a correlation between exercise self-efficacy and team sports involvement. There are 11 questions on a seven point Likert scale.

**Components of Exercise Motivation Questionnaire**

This full exercise motivation instrument measures the affective attitude (pleasure/enjoyment) (.76), instrumental attitude (worth, utility) (.78), subjective norm (social influence) (.72), perceived behavior control (capability/efficacy) (.86) and intention (.93) when playing exercise video games [79, 70]. We used only the 11-item enjoyment sub-scale on a seven point Likert scale.

**General Questionnaire**

This questionnaire gathered demographic data: players’ age, gender, hours spent gaming per week, and hours spent exercising per week using a five point likert scale. Hours spent exercising was defined as time specifically allocated to exercise. Depending on the experiment, players were asked to pick a preference between two experimental conditions. They were required to explain what they did and did not enjoy about the game, and were encouraged to suggest improvements to the game. There were a total of 11 questions, five of which were open-ended.

**4.2.3 Use of Actors**

In each condition, participants were paired with one of three actors. Actors followed a script dictating their behavior with participants. They acted with a friendly demeanor and did not initiate conversation. However they were allowed to respond to
participants’ comments or questions.

The experiments focused on the cyclist’s experience. In order to give consistency of experience to the cyclist and to reduce the complexity of the experiment, we used actors to play the role of the swatter.

In the single-player version of the game, participants were told the computer would handle swatting. In reality, an actor played as the swatter. This allowed us to provide consistency in play between the single and two-player conditions. Actors played in the distributed room to provide the illusion of a computer-controlled (AI) swatter.

### 4.3 Data Analysis

Data were analyzed primarily using SPSS. The first step was to reverse code negatively phrased questionnaire items. Next, items for each questionnaire were summed to create an overall score. For example, all of the self-efficacy items were combined into a self-efficacy score. Summed scores for each questionnaire were used in the analysis. P-values measure the probability that an observed statistical result would occur given that the null hypothesis is true. A t-test yields a t-value which assesses whether the means of two groups are statistically different from each other. The Pearson product-moment correlation (r-value) determines the degree that quantitative variables are linearly related in a sample [38].

### 4.4 Experiment 1

Group exercise in the traditional sense refers to physical activity in a co-located setting. The exercise motivation literature states that this form of group exercise
This first experiment attempted to investigate our first hypothesis; that people find collaborative exercise video games more enjoyable and engaging than single-player exercise video games.

For this experiment, ten participants (7 M; 3 F) were recruited. Ages ranged from 18-19 (n=4); 20-21 (n=3); 22-23 (n=1); and 25 or older (n=2). Only two of the participants had never used a recumbent bicycle. Five subjects stated they did not play video games on a weekly basis. Table 4.1 shows the frequency of these activities for all participants. The experiment followed a within-subjects design and the ordering of the conditions was randomized. One of three actors portrayed the computer AI or the swatter.

Questionnaires were administered to the participants before the tutorial, after each of the conditions, and at the end of the experiment. After the experiment was completed, participants were debriefed, the actors were revealed, and any questions were answered.

This experiment had two conditions. In the first condition, participants played a single-player version of Frozen Treasure Hunter. In the second condition, they played a multiplayer version of the game.

<table>
<thead>
<tr>
<th>Hours/week spent:</th>
<th>0</th>
<th>1-2</th>
<th>3-5</th>
<th>6-10</th>
<th>10+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercising</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Playing video games</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.1: Time participants spend exercising or playing video games each week for experiment 1
### 4.4.1 Condition 1: Single-Player

In the single-player version of the game, participants played the role of the cyclist. They were told that computer AI would handle the swatting. In reality, an actor played as the swatter. Participants played in the main room while the actor acting as the AI swatter played in the distributed room.

### 4.4.2 Condition 2: Multiplayer

The multiplayer version of the game was played in a distributed setting. Participants played as the cyclist in the main room, while the swatter played in the distributed room. An actor acted as the swatter; however, participants were told the swatter was another participant.
Table 4.3: Paired Samples T-test for multiplayer and single-player enjoyment and engagement

4.4.3 Experiment 1 Results

We compared participants’ enjoyment and engagement on multiplayer versus single-player tasks using a paired samples t-test. Summed enjoyment and engagement scores were out of 77 and 112 respectively (table 4.2). There was no significant difference between participants enjoyment, \( t(10) = 1.277, p = .234 \). However there was a significant difference in engagement, \( t(20) = 2.366, p = .042 \) between these two conditions (table 4.3). Nine out of ten participants stated they preferred the multiplayer version of the game.

Although enjoyment scores were not significantly different, enjoyment was greater for the multiplayer version of the game. Participants rated their enjoyment of both versions of the game highly. On average, multiplayer scored 66.1/77 while single-player scored 62.7/77.

In summary, on all three measures used, the two-player version scored higher than the single-player; in the case of the engagement and simple preference measures, the difference was significant.
4.5 Experiment 2

Results from experiment 1 indicated there was a clear preference of multiplayer over single-player exercise games. However, multiplayer exercise games can be played in a co-located or distributed setting. Each setting provides a different experience. Co-located play allows players to have physical interactions with their partners. On the other hand distributed play allows players to play anonymously. Therefore it is not obvious whether players might prefer one over the other.

Preference of play setting may also differ depending on players' self-efficacy. People with low exercise self-efficacy may not enjoy exercising in front of others. Therefore they may prefer playing in a distributed setting. On the other hand, players with high exercise self-efficacy are confident in themselves. They may prefer the face to face interactions possible with co-located play. Therefore they may have a preference of co-located over distributed play.

This experiment attempted to address two of our hypotheses. We first hypothesize that distributed group exercise is just as enjoyable and engaging as co-located group exercise. Secondly, we believe that people who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers.

To test our hypotheses, our second experiment had two conditions. In the first condition, participants played a co-located version of the game. In the second condition, they played a distributed version of the game. Questionnaires were used to determine players’ self-efficacy. These results will help us determine if self-efficacy is a predictor in players’ preference of co-located or distributed play.

For this experiment, 20 participants (12 M; 8 F) were recruited. Ages ranged from 18-19 (n=5); 20-21 (n=7); 22-23 (n=5); and 25 or older (n=3). Only 4 of the
participants had never used a recumbent bicycle. Two subjects stated that they did not exercise at all, and three did not play video games on a weekly basis. Table 4.4 shows the frequency of these activities for all participants.

The experiment followed a within-subjects design and the ordering of the conditions were randomized. In each experiment, two actors were used to play as swatters. One actor played in the co-located setting, the other in the distributed setting.

Participants played the games three times during the experiment. One tutorial session was provided at the beginning to familiarize players with the game. Participants then played the co-located and distributed versions of the game. Questionnaires were administered to the participants before the tutorial, after each of the conditions, and at the end of the experiment. After the experiment was completed, participants were debriefed, the actors were revealed, and any questions were answered.

Our second experiment had two conditions. In the first condition, participants played a co-located version of the game. In the second condition, they played a distributed version of the game.

### 4.5.1 Condition 1: Co-located Play

In the co-located version of the game, both players played in the main room. Participants played as the cyclist while actors played as the swatter. Participants were told

<table>
<thead>
<tr>
<th>Hours/week spent:</th>
<th>0</th>
<th>1-2</th>
<th>3-5</th>
<th>6-10</th>
<th>10+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercising</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Playing video games</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 4.4: Time participants spend exercising or playing video games each week for experiment 2
4.5.2 Condition 2: Distributed Play

In the distributed version of the game, players were physically located in different locations, however both players shared control of the avatar. Although players were not physically together, they played virtually together through their controlled avatar. Participants played as the cyclist in the main room, while actors played as the swatter in the distributed room. Once again, participants were told the swatter was another participant.

4.5.3 Experiment 2 Results

Players rated their enjoyment of the co-located and distributed games as 63.8/77 and 62.5/77 respectively (table 4.5). They also rated their engagement of the co-located and distributed games as 87.3/112 and 90.9/112 respectively.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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<tr>
<td>Pair 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-located Enjoyment Sum</td>
<td>63.80/77</td>
<td>20</td>
<td>6.45307</td>
<td>1.44295</td>
</tr>
<tr>
<td>Distributed Enjoyment Sum</td>
<td>62.45/77</td>
<td>20</td>
<td>8.41974</td>
<td>1.88271</td>
</tr>
<tr>
<td>Pair 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-located Engagement Sum</td>
<td>87.30/112</td>
<td>20</td>
<td>17.04205</td>
<td>3.81072</td>
</tr>
<tr>
<td>Distributed Engagement Sum</td>
<td>90.90/112</td>
<td>20</td>
<td>15.01543</td>
<td>3.35755</td>
</tr>
</tbody>
</table>

Table 4.5: Paired Samples Statistics
We compared participants' enjoyment and engagement on distributed versus co-located tasks using a paired samples t-test. There was no significant difference between participants' enjoyment, $t(20) = 1.318$, $p = .203$, or engagement, $t(20) = 1.703$, $p = .105$, between these two conditions (table 4.6).

We were interested in whether team participation and exercise self-efficacy had an effect on players’ enjoyment or engagement of the game. These results would describe how exercisers (high exercise self-efficacy) and non-exercisers (low exercise self-efficacy) feel about exercise video games in terms of enjoyment and engagement.

<table>
<thead>
<tr>
<th>Paired Samples Test</th>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error Mean</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Co-located Enjoyment Sum - Distributed Enjoyment Sum</td>
<td>1.35000</td>
<td>4.57999</td>
<td>1.02412</td>
<td>-.79350</td>
<td>3.49350</td>
</tr>
<tr>
<td>Co-located Engagement Sum - Distributed Engagement Sum</td>
<td>-3.60000</td>
<td>9.45571</td>
<td>2.11436</td>
<td>-.802541</td>
<td>.82541</td>
</tr>
</tbody>
</table>

Table 4.6: Paired Samples T-test for Distributed and Co-located enjoyment and engagement

<table>
<thead>
<tr>
<th>Enjoyment</th>
<th>Engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed</td>
<td>Co-located</td>
</tr>
<tr>
<td>$r$.078</td>
<td>$r$.367</td>
</tr>
<tr>
<td>$p$.744</td>
<td>$p$.494</td>
</tr>
</tbody>
</table>

Table 4.7: Pearson correlations for team participation and self-efficacy for distributed and co-located enjoyment and engagement

We compared participants’ enjoyment and engagement on distributed versus co-located tasks using a paired samples t-test. There was no significant difference between participants' enjoyment, $t(20) = 1.318$, $p = .203$, or engagement, $t(20) = 1.703$, $p = .105$, between these two conditions (table 4.6).

We were interested in whether team participation and exercise self-efficacy had an effect on players’ enjoyment or engagement of the game. These results would describe how exercisers (high exercise self-efficacy) and non-exercisers (low exercise self-efficacy) feel about exercise video games in terms of enjoyment and engagement.
Pearson correlation analysis was used to examine relationships among these variables (table 4.7). None of these relationships were statistically significant. Findings indicated a positive correlation between exercise self-efficacy and team participation, $r(20) = .447$, $p < .05$.

Results indicated that there were no significant differences in participants’ enjoyment of or engagement in co-located versus distributed tasks. This was reflected in the 50% split in participants’ responses when asked to state a preference for the co-located or distributed versions of the game. Open-ended comments on the final questionnaire indicated that participants had a difficult time choosing a preference between the two versions and commonly had positive comments for both versions of the game despite preferring one over the other.

4.6 Discussion

In experiment 1, we tested our hypothesis that players preferred multiplayer over single-player exercise video games. We did this by having players play both multiplayer and single-player versions of Frozen Treasure Hunter. Our results showed that Nine out of ten participants preferred multiplayer. Both the engagement and enjoyment scores were higher for the multiplayer condition, although only the difference in engagement scores was significant. Open-ended comments on the final questionnaire also strongly indicated participants’ preference of the multiplayer version.

One participant who preferred multiplayer play stated: “It was fun to be able to co-operate with someone and it was certainly more engaging than playing alone with a computer. In any case I find that most games are simply more fun in multiplayer than playing alone. It adds an element of strategy and stresses teamwork.”
The one participant who preferred single-player stated: “I thought there was not much difference between the multiplayer and single-player game. Since my other partner was just only doing what the computer was doing in the single-player environment.”

These generally positive comments and participants’ preference scores show a preference for multiplayer play. This lends support to our hypothesis that people prefer collaborative exercise to single-player exercise games. We conclude that, at least for Frozen Treasure Hunter, players preferred group exercise video games because it was more enjoyable and engaging. There is also evidence that suggests enjoyment and preference of exercise is a good predictor of exercise adherence. This may be true with our game, but longitudinal studies will be required to provide evidence of improved adherence. Designers of exercise games should therefore consider including a multiplayer component to their exercise games.

In experiment 2, we attempted to investigate two hypotheses. These hypotheses were: distributed and co-located exercise is equally enjoyable and engaging, and exercisers and non-exercisers find collaborative exercise games equally enjoyable. We tested our hypotheses by having players play both co-located and distributed versions of Frozen Treasure Hunter.

Our results indicated that there were no significant associations between participants’ self-efficacy or team participation scores and their enjoyment and engagement for either the co-located or distributed conditions of the game. This supports the hypothesis that people with low or high self-efficacy equally enjoyed and were engaged by this collaborative exercise game. While it is possible that a difference would become apparent with a larger sample size, it appears likely that any such difference
would be small, and therefore of no consequence to game designers.

Our tests showed very weak correlations between self-efficacy and enjoyment and self-efficacy versus engagement (both with $r(20) = .18$). In contrast, Rhodes reports that correlations for standard exercise are moderate ($r=.30$ to $.50$) [69]. We cautiously conclude from this that, unlike traditional sport, enjoyment of exercise video games may be independent of exercise self-efficacy. This issue deserves further study, as it indicates that players of exercise games may not find low self-efficacy a barrier in the same way as traditional exercisers.

Further good news for designers of exercise video games is that players equally enjoyed co-located and distributed play settings. Comments from players referenced enjoyable properties of both versions of the game. One participant who preferred distributed play stated: “for the sake of working out, I find it easier to put in more effort when there isn’t someone near that I have to interact with. It [co-located] did however make the game more intense.”

Another participant who preferred co-located play stated: “With a partner in the same room, it was more relaxed feeling. It was much easier to really understand our two different tasks. However I felt more absorbed in the game with a partner in another room.” This is positive information for designers of distributed video games, because it appears that collaborative play does not need to occur in the same room to be enjoyable or engaging. Distributed play may therefore be ideal for games with an exercise component since it allows players to exercise over a distance.
4.7 Limitations

These experiments used relatively small samples derived from a university population. Most of the respondents were 25 years old or younger. Participants were also unfamiliar with their partners. These results might change if the game were played amongst friends. These experiments should be generalized to other samples. However, our samples were not biased in terms of gender, or frequency of exercising or playing video games.

Self-efficacy scores and self-reported hours per week were used to gauge whether players were exercisers or non-exercisers. However, it should be noted that we used self-efficacy as a proxy or predictor of exercise activity. Therefore it may not be a completely accurate measure of player’s physical activity levels. Additionally, it may be possible that the actual and self-reported hours of exercise differ for participants. Therefore there may be limitations to the accuracy of players’ responses with their actual time spent exercising.

Although the actors were trained to behave in a uniform manner towards all participants, we cannot guarantee that there were no differences in their behavior between sessions. The fact that there were no significant differences between conditions implies that these possible differences are not a significant factor in the results.

We used a subset of questions from the components of exercise motivation questionnaire. The subset used measured affective and instrumental attitude. Research from Rhodes et al. has determined that attitude is an effective predictor of exercise intention [68]. However, it should be noted that this prediction may be less accurate due to our use of a subset of the questionnaire. Additionally, we did not directly
measure adherence to play our game. Instead we used the previously mentioned enjoyment and engagement scales, and preference of play as proxy measures. There is evidence that suggests enjoyment [78, 35, 4] and preference [13, 75, 33] of exercise is a predictor of exercise adherence.

Our results are specific to our Frozen Treasure Hunter game. The design of this game was informed by the exercise motivation literature. Future experimentation should examine the effectiveness of individual design decisions, such as the choice to use cooperative versus competitive play.

4.8 Conclusion

In previous chapters, we examined how the literature touted the benefits of grouping. These benefits were increased exercise participation and adherence. However, the exercise motivation literature examined these benefits in the context of traditional physical activity. It is not obvious whether these benefits also apply to exercise video games. Using our game, Frozen Treasure Hunter, we performed experiments to determine if the benefits apply to exercise games.

This chapter reported on our evaluation of three hypotheses about exercise video games. Our hypotheses were: people find collaborative exercise games more enjoyable and engaging than single-player exercise games; distributed group exercise is just as enjoyable and engaging as co-located group exercise; and people who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers.

The results of our experiments support our hypotheses performed with Frozen Treasure Hunter. Nine out of ten players preferred multiplayer over the single-player version of the game. Both exercisers and non-exercisers equally enjoyed the game.
The game was also equally enjoyable and engaging whether played in a distributed or co-located setting. However, more research will be needed for further evidence.

Developers of exercise video games should strongly consider integrating multiplayer interaction into their games. Unlike traditional exercise, multiplayer exercise games appear to appeal to people with low exercise self-efficacy. This is a very promising approach for helping challenging populations to increase their physical activity.

Ideally, exercise games should have both distributed and co-located multiplayer options, providing players with the ability to exercise in any setting. However, if developers are forced to choose only one setting, both choices appear to be equally beneficial to players. Furthermore, developers can be reassured that it appears to be possible to design exercise video games that appeal equally to players with low and high exercise self-efficacy.

Before concluding this thesis, the next chapter provides an overview of the implementation of Frozen Treasure Hunter.
Chapter 5

Implementation

In chapter 3 we introduced our two exercise games, Life is a Village and Frozen Treasure Hunter. The purpose of Life is a Village was to provide a long term single player experience. Although both games have different goals, some game requirements are shared between the games. Because both games shared game requirements, Life is a Village provided a strong base to begin creating Frozen Treasure Hunter.

In chapter 4, we discussed how we used Frozen Treasure Hunter to conduct experiments on the effectiveness of exercise video games. This chapter provides an overview of the game’s implementation. Using Life is a Village as a starting point, we explain how we created a new game involving multiplayer treasure hunting. Some software components from Life is a Village were reused. We will describe the implementation of Frozen Treasure Hunter using a high-level diagram of its architecture.
Development of Frozen Treasure Hunter was made possible by using relevant components of Life is a Village. Assets such as the art, the Ogre graphics engine, and some existing game systems were reused. To create Frozen Treasure Hunter, I implemented systems for enemy behavior, projectile defense, collision detection, integration of the Wii Remote and Nunchuk, collection system, vegetation system, and upgrade system. I modified the existing user interface, and added particle and sound effects.

The architecture of Frozen Treasure Hunter is composed of four high level categories, I/O Devices, I/O Interfaces, Game, and Game Data. These categories represent the layers of abstraction of the game, shown in figure 5.1 using the fiaa notation [63].
Display devices allow players to see the highest level abstraction of the game. Players provide input through I/O devices. This input is then processed through the I/O interfaces. The input data is used in conjunction with the raw game data to advance the gameplay. We briefly discuss the notation used in our diagram before describing each of our high level categories.

5.1.1 Fiia Notation

Components are the objects or classes that make up a piece of software. Components can be actors (⊙), reactors (□), or stores (□). Component actors contain a thread of execution, reactors respond to calls from actors, and stores are passive containers of data.

Physical hardware, or adapters, that players interact with are identified by A. Call connectors (identified by the single headed arrow) allow synchronous calls to be made between two components. Stream connectors (identified by the double headed arrows) allow for asynchronous event streams between two components.

5.1.2 Players

In Frozen Treasure Hunter, the players are the cyclist and swatter. To interact with the game, the players interact directly with the I/O Devices component. The bicycle and gamepad are used by the cyclist to move the in game avatar. Swatters use the Wii Remote and Nunchuk to swat snowballs. Both players view and hear the game via displays and speakers.
5.1.3 I/O Devices

The I/O Devices are represented by the display, bicycle, gamepad, Wii Remote and Nunchuk, and speakers. Output provided by the graphics engine updates the display. Similarly, output from the sound engine is sent to the speakers.

Input from the gamepad is interpreted via the input manager located in the I/O interfaces component.

Data read from the Tunturi E6R recumbent bicycle include torque, tension, and power. This information is transferred via byte code and is interpreted via the input manager [36].

We used GlovePIE to integrate the Wii Remote and Nunchuk into the game [44]. GlovePIE is a scripting language that allows devices to emulate joystick or keyboard input. A simple script was created in GlovePIE to map controller acceleration to swatting commands in Frozen Treasure Hunter. The Wii Remote and Nunchuk communicate via bluetooth signals. A BlueSoleil bluetooth connector was used to connect the controllers to the game. Also, Skype was used to allow players to communicate in the distributed version of the game.

5.1.4 I/O Interfaces

The I/O Interfaces act as the bridge between the game and the I/O devices, providing high level interpretation of input and sound effects output. All input from the I/O devices is interpreted via the input manager into usable data for the game. After interpretation, data from the bicycle, gamepad, Wii Remote and Nunchuk can be used in the game.
We used Ogre and OgreAL to power the graphics and sound engine. *Object-Oriented Graphics Rendering Engine* (Ogre) is an open-source 3D graphics rendering engine. Ogre abstracts the low level graphical details into high level classes [65]. Ogre also supports third party add-ons such as OgreAL. *OgreAL* is an extension for Ogre that integrates audio and 3D applications based on OpenAL [66, 67].

### 5.1.5 Game

The *Game* is the core of Frozen Treasure Hunter. The game component contains a main frame loop responsible for updating the game. Every frame, this component must poll the other components to retrieve input and provide the output necessary to simulate the game. The artificial intelligence (A.I.) handles the enemy behavior. Behaviors such as attacking, and sleeping are handled in this component.

### 5.1.6 Game Data

*Game data* is composed of user data and game world data. The *user data* represents information about the player’s state. *Game world data* is used by the game, graphics, and sound engine. Data used by the game affects states in the game world. The graphics engine uses game world data to update the models, graphics, and particles. Finally, the sound engine uses the game data to trigger audio events.

### 5.1.7 Additional Systems

Additional systems were modified or included to add audio and visual flair and improve usability. These systems were integrated into the game component. Particle effects, such as in-game sparks and snowflakes, were created using the Ogre Particle
Figure 5.2: Upgrade System

Editor. Once created, particles were integrated into the game using Ogre’s built-in particle systems.

Sound was integrated into the game using OgreAL. Sound and music was retrieved from the public domain. OgreAL restricts the number of simultaneous sounds that can be played at once. Therefore systems were created to dynamically manage the audio experience.

An upgrade system (figure 5.2) was created to allow players to improve their character over time. As players completed quests, they could improve their speed or defense. During an upgrade, the game would pause and players would make their choice. This involved implementing new games states and modifiers to the avatar. Visual cues provide visual feedback when choosing upgrades. Images of a fist and foot
represent each upgrade. An on screen icon represents each player’s choice. Cyclists and swatters are represented by a steering wheel and Wii Remote respectively. Both the images and icons were created using particle effects.

Vegetation in the form of dynamically generated grass was implemented using PagedGeometry [43]. PagedGeometry is an add-on to Ogre which provides highly optimized methods of rendering small meshes such as grass and trees.

5.2 Conclusion

In this chapter, we reviewed the high level architecture of Frozen Treasure Hunter. Beginning with Life is a Village, I introduced and extended various components to create Frozen Treasure Hunter. These components were displayed in an architecture composed of four high level categories representing the layers of abstraction of the game. These categories were the I/O Devices, I/O Interfaces, Game, Game Data. There was also a player category that interacted with the system. Not shown in the architectural diagram were additional systems implemented in the game component. These additional systems were implemented to add audio and visual flair and improve usability. Now that we have described our implementation of Frozen Treasure Hunter, we conclude this thesis in the next chapter.
Chapter 6

Conclusion

The incidence of obesity has increased dramatically over the past two decades. One approach to addressing this issue is to motivate people to exercise by embedding physical activity within video games. The idea is that the fun of video games will be a sufficient motivator for players to continue exercising. The commercial success of Dance Dance Revolution [42] and Wii Sports [62] demonstrates that it is possible to create fun games with an exercise component. However, other video games that involve physical activity, such as the EyeToy [29], have been less successful at attracting players. Currently, there is little understanding of what factors lead some exercise games to succeed while others fail.

We examined existing exercise games and the exercise motivation literature in chapter 2. The free motion interface of Kick Ass Kung-Fu and equipment based interface of Flyguy show that a wide range of different user interfaces are possible with exercise games. The virtual world of Push’N’Pull and augmented reality of Human Pacman show different ways of presenting game worlds to players. We saw from these examples that many unique exercise games are possible through different
combinations of game worlds and user interfaces. These exercise games share the common goal of improving peoples’ motivation to exercise. However, there has been little attempt to analyze what makes a successful exercise game. In chapter 2, we discussed the exercise motivation literature. This revealed that there are five factors that affect exercise motivation: music, instructor, exercise role-identity, peer support, and self efficacy. These factors have been shown to affect people’s motivation to exercise in the exercise domain. Using these factors, we developed a list of game requirements in chapter 3. Exercise video games should:

- Integrate music
- Hide players’ fitness level
- Provide achievable short and long term goals
- Facilitate leadership for novice players
- Remove barriers to grouping
- Actively assist players in forming groups

We illustrated these requirements using two custom-built exercise video games. The first game, Life is a Village, illustrated how game requirements intended to increase long term exercise motivation can be implemented. The second game, Frozen Treasure Hunter, illustrated how multiplayer game requirements can be implemented. An overview of Frozen Treasure Hunter’s implementation was discussed in chapter 5.

After examining the exercise motivation literature and developing game requirements, we decided to focus on questions pertaining to collaborative exercise. Much of the literature advocates the benefits of grouping, mainly that exercising in groups
increases exercise adherence and participation. These benefits are true with traditional exercise. However, it is unclear if they still apply to collaborative exercise video games. We investigated three hypotheses:

- People find collaborative exercise video games more enjoyable and engaging than single-player exercise video games.
- Distributed group exercise is just as enjoyable and engaging as co-located group exercise.
- People who are not exercisers enjoy collaborative exercise video games as much as people who are exercisers.

In chapter 4, we experimentally investigated these hypotheses on collaborative exercise video games. We performed two experiments using our game, Frozen Treasure Hunter. In experiment one, nine out of ten players preferred multiplayer over single player. Players were also significantly more engaged in the multiplayer game. These results, supported our hypothesis that players prefer multiplayer over single player exercise games.

In experiment two, there was an equal split between players’ preference of distributed and co-located play. Enjoyment and engagement scores were equally high for both versions of the game. Players’ preference of distributed or co-located play was not affected by self-efficacy or team participation scores. This implies that players enjoyed both versions of the game regardless if they were exercisers or non-exercisers. With these results, we concluded that distributed and co-located versions of the game are equally enjoyable and engaging.
Additionally, both exercisers and non-exercisers found the game equally enjoyable and engaging; this compares favorably to traditional exercise where exercise self-efficacy is correlated with enjoyment. This implies that people with low exercise self-efficacy view exercise games as different from, and less intimidating than traditional exercise. These results show promise in introducing non-exercisers to physical activity via exercise video games. It is possible that exercise video games may act as a gateway for people, helping them to discover they actually enjoy exercise.

Our results indicated that game designers should consider integrating multiplayer components into exercise games. Such multiplayer components can be either distributed or co-located as both are equally enjoyable and engaging. Finally, developers can be assured that as long as the game is fun, both exercisers and non-exercisers will find exercise games enjoyable.

6.1 Future Work

There is a small body of literature that examines the effectiveness of exercise video games. Therefore this young field has many paths for future research. In this research, we examined the motivational benefits of collaborative exercise games. As we mentioned in the exercise motivation literature, other factors exist that can be tested. Future research should examine the effects of music, instructor, and exercise role-identity on exercise motivation in exercise games.

Limitations from our study, such as small sample size and short duration, could be addressed with future research. Larger sample sizes, possibly from outside of a university population, would provide a broader understanding of the effectiveness of multiplayer exercise games. Our short term results indicate that multiplayer exercise
games are both enjoyable and engaging. Longitudinal studies will be required to determine if these motivational benefits are retained in the long run.

Alternative methods of tackling the fitness barrier can also be addressed. We used asymmetric tasks to allow players of different fitness levels to play together. It would be interesting to see if scaling mechanisms would also be effective. For instance, biometric feedback from players’ heart rate might be used to scale players’ performance in game. This would allow people of different fitness levels to play together.

6.2 Conclusion

This chapter concluded our thesis with a summary of the previous chapters. We briefly reviewed exercise games and the exercise motivation literature discussed in chapter 2. We reiterated the game requirements presented in chapter 3 and discussed how they were used to create two exercise games, Life is a Village and Frozen Treasure Hunter. Then the experiments and results were presented from chapter 4.

We concluded that non-exercisers’ disinterest with traditional exercise does not appear to hold true with exercise video games. With this research, we have shown that incorporating multiplayer play into exercise games appears to be a promising approach to encouraging non-exercisers to exercise. Additionally, regardless of distributed or co-located play, players of multiplayer exercise games will reap the possible motivational benefits of group exercise.

We have provided evidence that player enjoyment and engagement is greater with multiplayer exercise video games. With future studies, it may be possible to determine if players’ exercise participation and adherence is also increased with such
games. Future work should examine the effectiveness of other factors (music, instructor, role-identity) when applied to exercise games. Studies should also be performed to determine if multiplayer exercise games continue to be enjoyable and engaging in the long run.
Bibliography


Appendix A

Glossary

**Adherence:** The extent to which an individual continues an activity. For instance, adherence to an exercise program might be measured by attendance to that program [24, 53].

**Attitude toward the behavior:** Degree to which performance of the behavior is positively or negatively valued [3]. A component of the theory of planned behavior.

**Augmented reality:** Type of world created from a combination of real-world and computer-generated imagery.

**Behavior:** Observable response in a given situation with respect to a given target [3]. Defined in terms of its **target**, **action**, **context**, and **time elements**. An example of a behavior may be: *walking on a treadmill at a gym for 30 minutes daily for the next month*. Target: treadmill, action: walking 30 minutes daily, context: gym, time: next month [2].
Behavioral beliefs: One’s assessment of the probability that the behavior would produce a given outcome [3]. A component of the theory of planned behavior.

Control beliefs: One’s assessment of the presence of factors that may help or impede the performance of a behavior [3]. A component of the theory of planned behavior.

Cronbach’s alpha: Measure of the reliability of a psychometric instrument such as a questionnaire [30]. The alpha coefficient estimates how well a set of items can be used to measure a single variable [30].

Engagement: State of mind that evokes a feeling [47].

Exercise: Deliberately performed physical activity that requires exertion [64].

Exercise self-efficacy: Belief in one’s capabilities to organize and execute the courses of action required to perform exercise.

Game world: Characters, objects, and environments that together represent a game.

Intention: Measure of a person’s readiness to perform a given behavior [3]. A component of the theory of planned behavior.

Normative beliefs: Perceived behavioral expectations based on social influences such as family and friends [3]. A component of the theory of planned behavior.

Pearson product-moment correlation: Statistical technique that assesses the degree to which quantitative variables are linearly related in a sample [38].
**Perceived behavioral control** One’s perceptions of their ability to perform a given behavior [3]. Similar to self-efficacy. A component of the theory of planned behavior.

**P-value:** Value measuring the probability that an observed statistical result would occur given that the null hypothesis is true [38].

**Role-identity:** Behavior and characteristics that define how a person is viewed by them self and others [81, 21]. For instance, an exercise role-identity would be displayed by engaging in exercise.

**R-value:** Value resulting from a Pearson product-moment correlation that evaluates whether there is a linear relationship between two variables in the population [38].

**Salience of role-identity:** Degree to which someone identifies him/herself in a particular role-identity [21]. For instance, people with high exercise role-identity salience identify themselves as exercisers. Those who have low exercise role-identity salience do not identify themselves as exercisers.

**Self-efficacy:** “Belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations” [7].

**Standard error of the mean:** Standard deviation of the sampling distribution of the mean. [38].

**Standard deviation:** Amount of dispersion in a data sample [38].

**Subjective norm:** Perceived social pressure to engage or not to engage in a behavior [3]. A component of the theory of planned behavior.
**Theory of planned behavior:** Theory in psychology which attempts to understand human behavior [3]. Human behavior is guided by three considerations, behavioral, normal, and control beliefs.

**T-test:** Statistical technique that evaluates whether a mean on a test variable is significantly different from a constant [38].

**T-value:** Value resulting from a t-test that assesses whether the means of two groups are statistically different from each other [38].

**Virtual world:** Type of game world generated in a computer-simulated environment.
Appendix B

Participant Recruiting Poster
Participants Needed

Participants are needed in an experiment being carried out in the EQUIS Laboratory, School of Computing, at Queen's University. The experiment is on embedding exercise into computer games. The experiment lasts up to one hour. Results may contribute to the development of computer games with an exercise component.

Participants must
- Be ages 17 and up
- Have some experience in the past playing a computer game.
- Be able to perform light exercise on a recumbent bicycle
- Have no physical conditions which may contraindicate light exercise

You will be compensated $10 Movie Gift Certificate for your time.

If you are interested in being a participant in this experiment, please contact Jeffrey Yim by email at yim@cs.queensu.ca or by phone at (613) 533-6000 ext. 79310.

Thanks for your attention!

Study Ends: April 30th 2008
Appendix C

Measures
Exercise Self-Efficacy Questionnaire

This part looks at how confident you are to exercise when other things get in the way. Read the following items circle the number that best expresses how each item relates to you in your leisure time. Please answer by circling off the following 7-point scale:

<table>
<thead>
<tr>
<th>I am confident I will exercise even if...</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>My gym is closed.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am depressed.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>My significant other does not want me to exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I feel I don’t have the time.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>It’s cold outside.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am busy.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>My friends don’t want me to exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I have to exercise alone.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>The roads or sidewalks are snowy.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I don’t have access to exercise equipment.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am traveling.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am under a lot of stress.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I don’t feel like it.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>My exercise partner decides not to exercise that day.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am spending time with friends or family who do not exercise.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>It’s raining or snowing.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am alone.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I am anxious.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>
Positive Team Sports Involvement Questionnaire

The next few questions ask you about your experiences in *TEAM* sports, including practices, games and team fitness training sessions. Please rate how often the following things happen:

1 2 3 4 5 6 7
Never Sometimes Always

<table>
<thead>
<tr>
<th>When I am playing team sports:</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel confident.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>2. My teammates make fun of me.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>3. I look forward to other team activities.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>4. I feel embarrassed.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>5. My teammates encourage me.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>6. I feel like I’ve improved my skills.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>7. I feel like I don’t measure up to my teammates.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>8. I feel like I’ve learned something new.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>9. I feel like I’m really part of the team.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>10. I feel like I’m not good enough.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>11. I feel good about myself.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>
Components of Exercise Motivation Questionnaire (Only measuring attitude)
The following questions ask you to rate how you feel about exercising using this interactive video game over the next 6 weeks at your home/gym of choice. We define regular exercise on the bike as accumulating at least 30 minutes of activity, at least at a moderate level of intensity (i.e., slight perspiration), 3 times per week. Pay careful attention to the words at each end of the scales and circle the number that best represents how you feel about exercising on the game over the next 6 weeks.

For me, exercising on a game over the next 6 weeks at home/gym of choice would be:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>extremely enjoyable</td>
<td>moderately enjoyable</td>
<td>slightly enjoyable</td>
<td>neutral</td>
<td>slightly unenjoyable</td>
<td>moderately unenjoyable</td>
<td>extremely unenjoyable</td>
</tr>
<tr>
<td>2.</td>
<td>extremely useful</td>
<td>moderately useful</td>
<td>slightly useful</td>
<td>neutral</td>
<td>slightly useless</td>
<td>moderately useless</td>
<td>extremely useless</td>
</tr>
<tr>
<td>3.</td>
<td>extremely pleasant</td>
<td>moderately pleasant</td>
<td>slightly pleasant</td>
<td>neutral</td>
<td>slightly unpleasant</td>
<td>moderately unpleasant</td>
<td>extremely unpleasant</td>
</tr>
<tr>
<td>4.</td>
<td>extremely wise</td>
<td>moderately wise</td>
<td>slightly wise</td>
<td>neutral</td>
<td>slightly unwise</td>
<td>moderately unwise</td>
<td>extremely unwise</td>
</tr>
<tr>
<td>5.</td>
<td>extremely boring</td>
<td>moderately boring</td>
<td>slightly boring</td>
<td>neutral</td>
<td>slightly exciting</td>
<td>moderately exciting</td>
<td>extremely exciting</td>
</tr>
<tr>
<td>6.</td>
<td>extremely harmful</td>
<td>moderately harmful</td>
<td>slightly harmful</td>
<td>neutral</td>
<td>slightly beneficial</td>
<td>moderately beneficial</td>
<td>extremely beneficial</td>
</tr>
<tr>
<td>7.</td>
<td>extremely absorbing</td>
<td>moderately absorbing</td>
<td>slightly absorbing</td>
<td>neutral</td>
<td>slightly unabsorbing</td>
<td>moderately unabsorbing</td>
<td>extremely unabsorbing</td>
</tr>
<tr>
<td>8.</td>
<td>extremely miserable</td>
<td>moderately miserable</td>
<td>slightly miserable</td>
<td>neutral</td>
<td>slightly fun</td>
<td>moderately fun</td>
<td>extremely fun</td>
</tr>
<tr>
<td>9.</td>
<td>extremely frustrating</td>
<td>moderately frustrating</td>
<td>slightly frustrating</td>
<td>neutral</td>
<td>slightly fulfilling</td>
<td>moderately fulfilling</td>
<td>extremely fulfilling</td>
</tr>
<tr>
<td>10.</td>
<td>extremely gratifying</td>
<td>moderately gratifying</td>
<td>slightly gratifying</td>
<td>neutral</td>
<td>slightly ungratifying</td>
<td>moderately ungratifying</td>
<td>extremely ungratifying</td>
</tr>
<tr>
<td>11.</td>
<td>extremely deflating</td>
<td>moderately deflating</td>
<td>slightly deflating</td>
<td>neutral</td>
<td>slightly exhilarating</td>
<td>moderately exhilarating</td>
<td>extremely exhilarating</td>
</tr>
</tbody>
</table>
Engagement Scale Questionnaire (post-session)

This part provides statements about the exercise games you just played. Read the following items and circle the number that best expresses how you feel about the statement. Please answer by circling off the following 7-point scale:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I continued to play this game out of curiosity.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I could not do some of the things I needed to do while playing this game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I felt annoyed while playing this game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I felt discouraged while playing this game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I felt frustrated while playing this game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I found the organization of information in this game confusing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I liked the graphics and images used in the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>The game incited my curiosity.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>The organization of information in the game made sense to me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>The screen layout of the game was visually pleasing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This gaming experience satisfied my sense of curiosity.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game appealed to my visual senses.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game was attractive.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game was aesthetically appealing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game was easy to play.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Playing this game was taxing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game was stimulating</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>I didn't know what I was doing in this game</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>This game offered me sufficient navigation options</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
Engagement Scale Questionnaire (post-task)

This part provides statements about the exercise game you just played. Read the following items and circle the number that best expresses how you feel about the statement. Please answer by circling off the following 7-point scale:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I was playing the game, I lost track of the world around me.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>During this gaming experience I let myself go.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I blocked out things around me when I was playing this game.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I consider my gaming experience a success.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>The time I spent gaming just slipped away</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I was really drawn into the game</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I would play this game again voluntarily</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I forgot about my immediate surroundings while playing this game.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I lost myself in this gaming experience.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I was absorbed in my gaming task.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I was so involved in my gaming task that I ignored everything around me.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I was so involved in my gaming task that I lost track of time.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I would recommend playing this game to my friends and family.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>I would play this game in the future.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>It was easy to get wrapped up in this game.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>Playing this game was worthwhile.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>
General Questionnaire (Distributed vs Co-located): Page 1 of 3

OVERALL QUESTIONNAIRE

Date:  ________________
Age:  ________
Participant #: ________
Gender:  M  /  F

1. Before today have you ever used a recumbent bicycle before?
   □ No  □ Yes

2. How many hours per week do you play computer games?
   □ 0  □ 1-2  □ 3-5  □ 6-10  □ More than 10

3. How many hours per week do you exercise?
   □ 0  □ 1-2  □ 3-5  □ 6-10  □ More than 10

4. Which of the two setups did you find most enjoyable?
   Please rank from 1 to 2, 1 being the most enjoyable.
   □ Partner In Same Room  □ Partner in Separate Room

Please explain your choice:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
OVERALL QUESTIONNAIRE

Date: __________________________

Age: ________

Participant #: ________

Gender: M / F

1. Before today have you ever used a recumbent bicycle before?
   ☐ No    ☐ Yes

2. How many hours per week do you play computer games?
   ☐ 0   ☐ 1-2   ☐ 3-5   ☐ 6-10   ☐ More than 10

3. How many hours per week do you exercise?
   ☐ 0   ☐ 1-2   ☐ 3-5   ☐ 6-10   ☐ More than 10

4. Which of the two setups did you find most enjoyable?
   Please rank from 1 to 2, 1 being the most enjoyable.
   ☐ Single Player    ☐ Multiplayer

Please explain your choice:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
5. Based on your response to question 4, what aspects of the game did you find enjoyable?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6. What aspects of the game did you not find enjoyable?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

7. Are there any suggestions you would like to provide to improve the game?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
General Questionnaire (Distributed vs Co-located) or (Multiplayer vs Single player):
Page 3 of 3

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Additional Comments:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Thank you for participating and for your comments.