SMALL-SCALE EXERTION IN SPORTS VIDEO GAMES

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ABSTRACT

Sports video games should be inherently competitive, but they fall short in providing competition between player skills. The translation of real-world physical activities to a game controller and the emphasis on statistical simulations in traditional sports video games leads to a limited opportunity for expertise development, individual differentiation, and fatigue. These are three very important aspects of real-world sports that are lacking in sports video games. One possible solution to these difficulties is to use small-scale exertion. This method requires the design of an input mechanic that requires only the use of hands and fingers (or feet). We created two small-scale exertion sports video games (Track and Field Racing and Jelly Polo) and ran four studies to compare our small-scale exertion games to traditional rate-based sports video games. Qualitative and quantitative results suggest that using small-scale exertion increases the amount of expertise development, individual differentiation, and fatigue in sports video games. Results also suggest small-scale exertion controls are more engaging than traditional rate-based controls. By using small-scale exertion to add physicality into sports video games, we are able to increase richness, competitiveness, and realism in order to create a game which is competitive, in terms of player skill, and sport-like.

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This thesis is dedicated to my mother Tracey, and my father Randy; it is your love and support that has allowed me to succeed.

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LIST OF ABBREVIATIONS

FIFA	Fédération Internationale de Football Association
NFL	National Football League
NHL	National Hockey League
2D	Two-Dimentional
3D	Three-Dimentional
TaFR	Track and Field Racing
eSports	Electronic Sports
NBA	National Basketball Association
D-pad	Directional Pad
HCI	Human Computer Interaction
CHI	Computer Human Interaction
USB	Universal Serial Bus
EMG	Electromyography
fMRI	functional Magnetic Resonance Imaging
PC	Personal Computer

CHAPTER 1

INTRODUCTION

Sports are some of the most popular forms of entertainment. With all of the different types of sports, the number of leagues, the historic teams, the iconic players, and plethora of merchandise available, there is no debating that people around the world love sports. This love for real-world sports can also be seen in sports video games. The video game industry is one of the largest industries in the world and is steadily growing every year. It is even moving past the movie industry in revenue; the video game industry made $79 billion worldwide in 2012 and was estimated to make $93 billion in 2013 [32], whereas the global box office made less than $36 billion in 2013 [65]. The sports video game genre was the second leading genre in video game revenue in the past 5 years [47]. Since this form of entertainment reaches out to such a wide audience, it is important to take a closer look at the sports video game genre.

Two of the most important aspects of sports are the great physical feats displayed by the athletes (e.g., running at amazing speeds, performing an acrobatic dunk of a basketball on a 10-foot-tall net, etc.) and the competitive nature of sports. The athletes, or *players*, are the reason sports are entertaining. *Players* of a video game, in contrast, are the people holding the controllers. They are the ones controlling the video game. One part of moving from the real world to video games is the translation of the interactions performed by the players. Many sports video games contain elements such as running or throwing that are based on real-world physical activities, but the translation of these activities to game controllers means that the original physicality is lost (e.g., think of the amount of physical and mental effort needed to throw a football to a receiver compared to simply pressing a button on a controller). Such limitations can create problems for sports video games. For example, a novice can be just as good as an expert in terms of moving a character at maximum speeds because the only skill needed is to be able to hold the thumbstick of a controller down to one side. Players cannot get better at holding a thumbstick down, and there is little variability in different people's ability.

1.1 PROBLEM

The problem to be addressed in this thesis is: sports video games are very different from real world sports, making sports video games less of a realistic experience for players.

Sports video games – such as *FIFA Soccer* or *Madden NFL* – let people play their favorite team sports in a computer simulation. These games provide highly realistic graphics and movement using motion capture techniques and actual visuals of real players and stadiums. However, although the appearance of on-screen characters and environments in these games are very similar to the real world (see Figure 1.1), other aspects are not like sports at all. In particular, the gameplay of sports video games involves simulations of expert physical actions such as running, throwing, and kicking – but these actions in the game are performed using techniques that are very much *un*-like the ways the athletes operate in the real world.

Figure 1.1: Screenshot of a realistic looking NBA sports video game, *NBA 2K15* [75].

Most sports video games use a standard game controller – with right and left joysticks (called thumbsticks), a directional pad, and a series of buttons – to control characters in the game (in this thesis, *player* will be used to refer to the human player, and *character* will be used to refer to the on-screen avatar). The actions that players perform to run, pass, throw, or shoot are all carried out with this controller – and are much the same regardless of which human player is at the controls. This is in stark contrast to real-world sports, where the ways that different athletes perform these actions is the basis of their skill level. For example, there are major differences in the way that a professional soccer player shoots compared to a beginner, but very little difference between two players of a sports video game (since both players shoot by pressing a button on the game controller). This leads to three main problems in sports video games:

- Expertise Development – There is limited opportunity for expertise development in traditional sports video games. Although there are many ways for a player to increase skill in a sports game (e.g., knowledge of strategy or which characters to choose), there is little opportunity for improvement of basic actions like running or throwing. In contrast, improvement in basic physical skills is a foundation for expertise in real-world sports.

- Individual Differentiation – There is little differentiation between players in terms of basic actions like running and passing, and thus little opportunity to use these differences in the game. In contrast, success in real-world sports often revolves around individual differences (e.g., taking advantage of a mismatch with an opponent's physical capabilities, or setting up a team to capitalize on individual strengths and minimize individual weaknesses).

- Fatigue – The artificial simplicity of controller actions means that there is no change in a player's physical capabilities over the course of a game. In real-world sports, effort-based factors such as fatigue clearly set apart better players and teams from weaker ones – e.g., many games are won and lost when the team with more endurance takes advantage of the other team's fatigue.

Overall, these drawbacks reduce the richness, realism, and competitiveness of sports video games. Although some games can add other types of richness (e.g., difficulty levels for computer players, minigames such as fighting in a hockey game, or ‘manager modes’), the core play experience of a sports game is often limited by these problems.

1.2 MOTIVATION

Currently, sports video games attempt to be the best simulation possible of the real thing. Characters look like their real-world counterparts, the animations of character movement are extremely life-like, and each in-game character is given different stats based on how good they are in real life. This realism – particularly the fact that each character is given a set of predefined statistics – is one reason why sports video games hinder the player experience. For example, Sidney Crosby is one of the best players in hockey. His profile in the latest NHL video game gives him very high stats because of this (a 95 overall rating, as shown in Figure 1.2). Now, imagine one player is controlling Sidney Crosby and another player, the opponent, is controlling a character that has much lower stats (e.g., a character with an overall rating of 60). If these two players are racing for the puck (i.e., the object of interest in a hockey game), the player controlling Sidney Crosby is going to win the race. This is not because that player is more skilled than the other player (even though he may be) but it is solely because the character he is controlling has better in-game stats than the other player’s character.

This lack of autonomy may cause frustration in the player. If an expert player, who has practiced many hours playing a sports video game, plays against a novice player who picks a higher rated team, the expert player is at a disadvantage. The competition involved is not based on the players’ physical skills, but the statistical simulation of the characters in the video game. At the moment, this may not be seen as a problem to sports video game players, or even developers, but we feel they are missing out on the opportunity for a more engaging and enjoyable game that is more sport-like and competitive. If some form of physicality could be brought into the game, these issues could be reduced significantly.

Figure 1.2: In-game statistics of Sidney Crosby in the latest NHL video game [79].

1.3 SOLUTION

The solution presented in this thesis is to add physicality into sports video games by using small-scale exertion.

We define small-scale exertion as the exertion of small muscle groups – such as fingers, hands, or feet – caused by small movements. We want to clearly distinguish small-scale exertion from large full-body exertion, where people jump, move back and forth, and swing their limbs. Large full-body interactions have been used in games before (including commercial games such as *Wii Sports*); but in some aspects, they are not a good solution to the problems facing sports video games [29]. Part of the problem of full-body exertion in games is that it takes away from the traditional sports game environment. Sports video games involve players sitting down, holding a controller, and facing the display. Full-body interactions with video games requires considerable space in front of the display, and different input devices (e.g., Microsoft Kinect); in addition, full-body exertion can lead to players getting too tired too fast, leading to less time actually playing the game. By moving the exertion to a smaller scale, we allow it to be carried out with a traditional controller, where players can still sit down, use traditional input devices, and play for longer time periods.

In order to translate real-world physicality into a game controller, we translate the game mechanics used for basic physical actions like running and throwing. There are many possible ways to map movement control to the available capabilities of a computer input device. Researchers have defined several properties of devices and the input relationship, including the property being sensed, the state being sensed, and number of dimensions sensed [45]. For example, a keyboard key senses only state (up/down) and a single dimension; a thumbstick on a game controller senses position in two dimensions.

The physical control schemes we built were designed for two activities - movement and throwing. *Impulse-based* movement was designed for both a keyboard and a game controller, and the goal was to mimic the physical effort needed to sustain movement in the real world. Real-world movement is based on repeated actions that provide a kinetic impulse to the body - taking one step moves the body by a certain amount. An impulse has both a direction and a magnitude, and the result of the impulse is an increase in velocity that fades over time. If another impulse is received before velocity reaches zero, higher velocities can be attained. Discrete versions of impulse-style controls were common in early handheld games (e.g., *Mattel Football*), where pressing direction buttons moved an on-screen character by one unit.

Impulse-based control can be implemented in several ways. On the keyboard, repeated alternating keypresses were used as the impulse signal - the magnitude of the impulse was fixed, and no direction was needed as the game involves a straight-line race. A more complex control scheme was developed using the thumbsticks of a game controller: each push of the thumbstick with the thumb represents a single impulse, with the amount of displacement providing the magnitude value, and the 2D position of the thumbstick providing the direction. Controller thumbsticks automatically return to centre, allowing the next impulse to be initiated immediately.

In addition to movement, a physical control scheme was designed for throwing (called *precision throwing*). Precision throwing requires that the user control two values: direction and distance. The properties of a thumbstick can be mapped to these values (2D position to direction, and displacement speed to distance), and so the second thumbstick of the game controller was used for arm movement and throwing, as will be discussed in Chapter 4. Also included was a threshold-based release mechanism so the ball in the game could be thrown without an explicit release switch.

To test this solution, two games were created which use small-scale exertion for movement. The first game is a very simplistic version of a small-scale exertion game and was meant to provide initial insight into this new area. The second game is the main contribution and is a more in-depth look into how small-scale exertion, specifically impulse-based movement and precision throwing, can affect a sports game. With physicality added into sports games, players now have more opportunity for expertise development, there is increased differentiation between players, and fatigue becomes an important gameplay element. Qualitative results were gathered first to determine how viable this type of game was and if the three problems mentioned above could be addressed. We then found quantitative evidence to empirically determine that the three main problems were in fact problems with current traditional controls and that small-scale exertion can help alleviate these problems. Finally, subjective enjoyment and engagement ratings were compared between the small-scale exertion version and a more traditional version of the same game.

1.4 STEPS IN THE SOLUTION

In order to make sports video games more competitive and sport-like using small-scale exertion, several steps were completed during the research process.

1.4.1 Step One: Define Rate-Based Movement

First, we must define rate-based movement in terms of video games. Rate-based movement is used in many sports video games for regular movement of a character. Movement is translated to a rate-controlled thumbstick action (i.e., hold the stick on the controller to move the on-screen character) or a fixed-rate keyboard action (i.e., press and hold the WASD keys to move). The important characteristic of rate-based movement is that the character moves at a constant rate (i.e., speed) when the thumbstick is held fully to one direction. There may be a continuous speed difference from the thumbstick's neutral position to the furthest displacement, but once it is fully displaced character speed can no longer increase. This step provided a basis for what we wanted to improve upon.

1.4.2 Step Two: Understand Previous Research

Second, it is important to examine the current state of exertion interfaces and exergames, and how to use these ideas for traditional video games. There are current exergames available, some commercially available, but they mostly need large novel interfaces and require substantial amounts of full-body exertion to use. This leads to games which cannot be played for extended periods of time without breaks. Our goal was to provide a solution by somehow using a keyboard or a traditional video game controller as an exertion interface. This step led to the use of small-scale exertion which is exertion that uses small movements of small muscle groups – such as fingers, hands, or feet. Small-scale exertion has the advantage that it does not require a large space and can be integrated into traditional game settings. The small-scale exertion games we created do not focus on exercise as some exergames do. Instead, these games focus on the enjoyment and game design factors small-scale exertion can produce.

1.4.3 Step Three: Explore a Simple Case of Small-Scale Exertion

Third, we wanted to examine how a simple form of small-scale exertion changed the game experience. This step focused on gathering insights about whether small-scale exertion could be a potential solution to the three main problems stated above. To do this, a game was created called Track and Field Racing (TaFR) – a running game where two players race each other in a simulated 100m, 200m, or 400m race. Players controlled the running movement by alternately pressing two keys on the keyboard, as fast as possible, with their index and middle fingers. We ran three tournaments with TaFR to see whether the physical controls led to individual differences and to performance changes over time. This step provided a game for testing a simple form of small-scale exertion.

1.4.4 Step Four: Create a More Robust Small-Scale Exertion Game Using the Traditional Game Setting

The fourth step was to create a game that could be integrated into the traditional game setting where people use standard controllers and sit in groups in front of a display. This game was called Jelly Polo, a 3-on-3 team-based game similar to hockey. Small-scale exertion was introduced in the form of impulse-based movement and precision throwing. Impulse-based movement is controlled by flicking the left thumbstick to give a pulse in the direction of the flick. The faster the player flicks the stick, the more pulses are given to the character and the faster they will move. Precision throwing was used instead of the traditional sports game technique of “auto-passing” (calculating the speed, trajectory, and direction of passes and shots for the player, requiring only a button press for input). With precision passing, players instead must rely on their skill, as throwing the ball is based on the exact direction and speed the right thumbstick is flicked. This step produced a more traditional sports video game for testing the effects of small-scale exertion.

1.4.5 Step Five: Study and Evaluate Small-Scale Exertion in a Sports Video Game

Four studies were conducted to evaluate the effects of small-scale exertion on expertise development, individual differences, and fatigue. The first study was to determine if the interactions created were viable in a traditional game environment and qualitatively determine player feelings towards the control scheme. The second study was to qualitatively determine skill increases, differentiation, and fatigue over a long-term Jelly Polo league. The third study was to quantitatively show that impulse-based movement is a potential solution the three main problems, in comparison with rate-based movement. The fourth study compared subjective enjoyment and engagement ratings between the impulse-based version of Jelly Polo and an identical rate-based version, where the only difference was the movement mechanic. This step allowed us to gain insight on how small-scale exertion affects sports video games.

1.5 EVALUATION

To provide information about small-scale exertion in sports video games, four studies were performed to test the effectiveness of two small-scale exertion games. By analyzing the results of each study we were able to identify an effective way of using small-scale exertion in the traditional game environment. In addition, we also determined how enjoying and engaging the control scheme compared to traditional control schemes. Results of the evaluation show that small-scale exertion increases the opportunity for expertise development, enables more individual differences between players, and changes players' physical capabilities throughout the course of a game due to fatigue. We also found that player engagement significantly increased using impulse-based movement and was similar in enjoyment compared to using rate-based movement.

The evaluation was broken down into four distinct parts, each discussed in its own chapter of this thesis:

- A tournament was held using a simple form of small-scale exertion in the game Track and Field Racing. We tested both individual differences and fatigue. Empirical results from this study were used to determine that small-scale exertion produces individual differences and causes fatigue which leads to changes in performance over the course of a game. It was also determined that the interaction technique used, which is common in some Olympic style video games, could not be sustained for longer periods of time without the risk of injury (e.g., repetitive strain injury).
- After the creation of a more sustainable control scheme using a traditional controller, we ran a Jelly Polo league where four consistent teams of three played three games a week

for four weeks. Game related statistics were tracked (e.g., shots, goals, assists, saves, etc.) programmatically and by video analysis. These statistics, subjective responses, and post-league interviews suggested that small-scale exertion used in Jelly Polo led to an increase in expertise development, an increase in individual differentiation, and allowed fatigue to become a major gameplay element.

- The second study gave empirical evidence that small-scale exertion does in fact increase expertise development, show individual differences, and causes fatigue in players. This study tested participant skills over three separate sessions spanning a week and a half; participants performed a number of specific tasks, including a race, an obstacle course, and a passing drill. These tasks were performed for impulse-based movement and rate-based movement (aside from the passing drill which did not depend on movement). The study showed that small-scale exertion using impulse-based movement increases expertise development and individual differentiation; fatigue was observed in the short-term (i.e., within tasks) but not in the long term (i.e., between tasks).

- To further test the effects of small-scale exertion on enjoyment and engagement, a second Jelly Polo league was run spanning six weeks with each team playing one game a week. Four teams of three were split into two separate groups; one group would play three weeks of the impulse-based version and then three weeks of the rate-based version and vice versa for the other group. Subjective ratings for enjoyment and engagement were recorded for each game version. The results for this study show a significant (although small) increase in engagement for the impulse-based version, but no difference in enjoyment rating for both versions.

1.6 CONTRIBUTIONS

The primary contribution presented in this thesis is demonstrating that small-scale exertion is a game-design factor that can improve richness, competitiveness, and realism.

First, we showed that a simple small-scale exertion game adds individual differentiation and fatigue as a game design element. Second, qualitative findings showed added expertise development, individual differentiation, and fatigue in Jelly Polo. Third, a quantitative comparison of small-scale exertion controls and traditional controls was made to determine that expertise development, individual variability, and fatigue can be found in the small-scale exertion version, but not in the traditional version. Fourth, a qualitative comparison was made between a game with small-scale exertion controls and the same game with traditional controls to determine similar enjoyment ratings but higher engagement ratings for the small-scale exertion version.

Several secondary contributions from this research were:

- The development of two small-scale exertion games – Track and Field Racing and Jelly Polo. One being a simple form of a small-scale exertion game and the other being a more advanced form of a small-scale exertion game.
- The first empirical baseline results of player performance over time using traditional rate-based controls.
- The first empirical baseline results of player performance over time using small-scale exertion controls.
- The first comparison between traditional rate-based controls and small-scale exertion controls in terms of expertise development, individual differentiation, fatigue, enjoyment, and engagement.

1.7 THESIS OUTLINE

The remainder of this thesis is organized as follows:

- Chapter 2 describes background information about exertion, sports video games, and exergames and how they are related. A brief look at the state of current sports video games and electronic sports (eSports) will be discussed first. Exertion interfaces and exergames will be examined next to give a better understanding of the area of research and commercial examples of existing exergames. It will also explain why we diverged from traditional research on exergames requiring full-body exertion and moved toward small-scale exertion. We will also look into previous research which has found relationships between real-world sports and sports video games. Exertion and fatigue will then be examined to give a brief overview of the physiology behind what we are doing. This information will be used to foreshadow expected quantitative results in our studies. This chapter ends with an explanation of the limitations of current sports video games.

- Chapter 3 reports the game description, study methods, results, and discussion from the initial study using a simplified form of small-scale exertion in a game called Track and Field Racing. The results of this study most notably include initial evidence of individual differentiation and fatigue.

- Chapter 4 reports the game description, study methods, results, and discussion from the second small-scale exertion study. This study uses the game Jelly Polo which is the main focus of the research. This initial look into how small-scale exertion can be used in a traditional game environment results in mostly qualitative data in terms of expertise development, individual differentiation, and fatigue.

- Chapter 5 reports the game description, study methods, results, and discussion from the second small-scale exertion study using Jelly Polo. This extension of the previous study focuses on empirically quantifying expertise development, individual differences, and fatigue in both impulse and rate-based versions of the game.

- Chapter 6 reports the task descriptions, study methods, results, and discussion from the third and final small-scale exertion study using Jelly Polo. This final extension of the previous research focuses on subjective ratings for enjoyment and engagement of both an impulse and rate-based version of Jelly Polo.

- Chapter 7 is a discussion and conclusion chapter to bring the results from each study together. A summary of the results is given as well as an attempt at generalizing them. Limitations of the approaches will be discussed here. Also, several recommendations for future work will be given. The chapter finishes off with a list of accolades Jelly Polo has received and ends with final conclusions.

CHAPTER 2

RELATED WORK AND BACKGROUND

This research is based on three key areas: sports video games, exertion interfaces, and exergames. In addition, in order to understand the addition of small-scale exertion to exergames, this chapter also provides a background of fatigue from a physiological perspective.

2.1 SPORTS VIDEO GAME BASICS

Sports video games are a genre of video games which simulate traditional real-world sports such as hockey, football, basketball, and soccer. Some sports video games focus on actually playing the sport (e.g., *NBA 2K15*) and some focus on the strategy aspect of sports (e.g., *Championship Manager*) [107]. Sports video games – such as *FIFA Soccer* or *Madden NFL* – let people play their favorite team sports in a computer simulation. One of the first video games ever made was a sports video game, called *Tennis for Two*, in 1958 [98]. As seen in Figure 2.1, *Tennis for Two* is a very simple looking game.

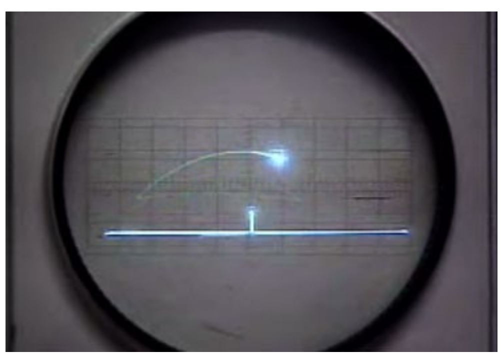

Figure 2.1: *Tennis for Two* on an oscilloscope [98].

As the years passed, new sports video games were made annually. The core mechanics of these games have stayed the same throughout; however, there have been improvements in graphics due to technological advances. Take hockey video games, for example. Hockey, in the real world, has not changed very much over its history. Many minor rule changes have been made, but the basic structure has always been the same; two teams play on ice to score more goals in a certain amount of time. Figures 2.2-2.4 show the transformation of hockey video games from the early Atari 2600 game console to the latest generation of consoles.

Figure 2.2: ***Ice Hockey*** **(1988) screenshot for the Atari 2600 [95].**

Figure 2.3: ***NHL 91*** **screenshot for the SEGA Genesis [30].**

Figure 2.4: ***NHL 15*** **screenshot for the Playstation 4 [92].**

People play a sports video game by controlling the actions of one of the on-screen athletes, at a time, often by manipulating buttons and thumbsticks on a standard game controller. Figures 2.5 and 2.6 show the offensive and defensive controls utilized by the Xbox 360 game controller for *NBA Live 14*. As one can see, there are many controls to worry about and completely different sets of controls depending on the situation (e.g., the 'A' button is 'Pass' on offense but 'Switch Player' on defense).

Figure 2.5: Offensive controls for ***NBA Live 14*** **[24].**

Figure 2.6: Defensive controls for *NBA Live 14* [24].

The sports video game genre was the second leading genre in video game revenue in the past 5 years [47]. Over that same time period there were, for example, more than 10 hockey video games released [105]. This means on average, more than two hockey video games are released every year. The same can also be said for other traditional sports like basketball and football. These games have made the genre a lot of revenue; *Madden NFL* as of 2013 has made over $4 billion and sold 99 million copies in its lifetime as a franchise [99]. This is a substantial number considering the list of sports the genre has to offer (e.g., hockey, basketball, football, soccer, boxing, golf, tennis, baseball, bowling, rugby, wrestling, etc.) [103].

There are many objectives and game mechanics associated with each type of sports video game. These objectives are the same as in real sports – score goals, and win games. There are several game activities that allow the human player to try and achieve these objectives (through the on-screen athlete). Below is a list of several common activities in sports video games, as well as common game mechanics that allow people to carry out those activities.

- Movement (e.g., running or skating): the player can control the movement of the on-screen character on the field of play. The most common game mechanic for movement is to use one of the joysticks (also called “thumbsticks”) on the game controller (see Figure 2.5). Sports video games translate thumbstick movement into character movement using a scheme called “directional rate control”, in which the direction of movement is determined by the direction of the thumbstick (e.g., the character moves left when the thumbstick is moved to the left), and the speed of the on-screen character is determined by the amount of displacement of the stick (e.g., the character moves at maximum speed when the stick is pushed all the way to its limit).

- Passing: this action is controlled in many different ways, but the most common is a single button. There may be different buttons used to perform different styles of passes (e.g., 'A' for a normal pass and 'B' for a lob pass) but they all work similarly: take the object of interest (e.g., the ball) from the current character and move it to another character on the same team. For example, consider how passing works in the NBA basketball video games. If a player holds a general direction with the movement stick, then presses the pass button, the game logic decides which character on the same team is in that general direction and determines the trajectory of the pass automatically so that it is successfully completed. Of course, there may be characters on the other team that are in the way to intercept the pass, but the game decides the pass logic automatically. In the simplest case, players need to only press the pass button, without pointing the movement stick in any direction, and the game will decide which character is closest and make a perfect pass to them. This automatic passing algorithm the game performs for its players makes for less skill involved in the action of passing.
- Shooting: this action is similar to passing. Before controllers used two thumbsticks (i.e., before the first Playstation console), shooting was a simple button press. Again, some buttons perform different styles of shots (e.g., wrist shot or slap shot in hockey) but it was still a single button press. Recently some genres like hockey and basketball use the non-movement thumbstick to change the style of shot taken. Different thumbstick combinations will perform different actions, but the success of a shot is still decided mostly by the game logic itself.
- Other activities: There are many common actions carried out similarly throughout the genre. Calling plays is a common action between most sports video games. This is carried out in many different ways, including the directional pad (D-pad) or a set of button combinations (e.g., left bumper + 'X' button to call for a screen in basketball). Another very common action, found in all sports video games with multiple teammates, is

switching characters. With multiple characters on a team, players are given the opportunity to play as any one of the characters. Usually, players control the character that is in possession of the ball. On defense, however, players can decide to choose whichever character they want to control. This is usually done by pressing a single button to switch characters. On defense, the game usually makes players switch to the character that is closest to the ball, but there are ways to decide on specific characters to switch to (e.g., click the right bumper to show a different button over each character in the game, then press the button corresponding to the character of choice to switch to them).

Sports video games are simulations of real-world sports, but as discussed earlier, they are unlike real sports in that there is very little actual exertion for the human player. In the next section, we look at a genre of games that has been considered in HCI research that focuses on adding actual exertion to interfaces and games.

2.2 EXERTION INTERFACES AND EXERGAMES

A large body of work studies exertion interfaces and their use in games (e.g., [15, 17, 18, 19, 27, 42, 50, 55, 58, 66, 67, 69, 109]). An exertion interface is one that requires some form of effort [66]. As a simple example, the MouseGrip system [72] is a mouse-based input device that adds components and sensors to afford a squeezing action to produce exertion (see Figure 2.7). This exertion interface is meant to be small and discreet so users can use it without taking up any extra space while making mundane tasks (i.e., mouse movement) more enjoyable – but exertion interfaces in general can involve any type of exertion that is part of the interaction with the computer system.

Figure 2.7: The mousegrip exertion interface from [72].

One commonly-studied type of exertion interfaces is exertion games, or *exergames*. An exertion game is one in which the player purposely expends physical effort through an exertion interface [71]. There are two main goals associated with exergames: one is to create healthier lifestyles and reduce health problems, mostly associated with lack of exercise; and the other is to use the experience of exertion as a factor in game design – for example, bringing the idea of contact sports into distributed video games [68]. It is important to note, however, that health benefits (although common in many exergames) are not required for the genre.

A taxonomy of exergames (Figure 2.9) has also been created which divides the design space into several categories [71]:

- Competitive: this type of exergame is one that has one or more opponents. An opponent can be defined as a human or computer player who is also trying to complete the goal of the game. The results of these types of games have to be comparable between players to help choose a winner. Exertion can be used in a competitive context in many ways. As an example, Remote Impact is an exergame where two remote players try to punch, kick, and slam into a mattress on the wall. Projected on the mattress is a silhouette of the other player. The harder the impacts to the silhouette on the mattress, the higher the score (see Figure 2.8).

Figure 2.8: Two players playing Remote Impact, from [67].

- Non-competitive: in contrast, these are games having no opponent. Other players may be playing to assist you in obtaining the game's goal (e.g., players on the same team in hockey), and not to be an obstacle preventing you from winning.

- Parallel and Non-Parallel: within the category of competitive exergames, these games can be designed so that players play either in a parallel or non-parallel fashion. This means that players play interactively in order to prevent the other player(s) from winning (i.e., non-parallel), or players perform independent activities and cannot influence the difficulty of the opponent's activities.

- Combat: non-parallel exergames can be split up even further. Combat games involve players trying to control their opponents. This could take the form of trying to lower the opponent's health, as in Duel Reality for example [26] (see Figure 2.16).

- Object: other exergames involve players trying to control an object of interest over their opponents. Airhockey over a distance [69] is an example of an Object oriented exergame. Players must play a digital version of air hockey by swinging a bumper into the digital representation of a hockey puck. The goal is to bounce the digital puck into the opponent's net. These opponents are fighting over possession and control over the puck, not directly hindering the activities of the opposing player.

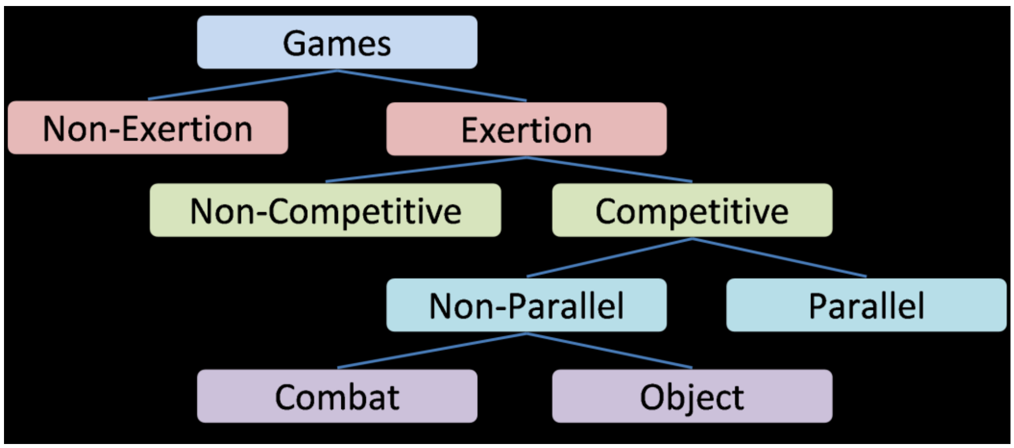

Figure 2.9: Exergame Taxonomy (adapted from [71]).

The first goal of exergames, to promote healthier lifestyles, was the main focus of exergames until recently. A review of exergames published in 2011 primarily discusses the health benefits of exergames [90]. A main concern of game designers has been trying to help with the problem of obesity [15, 36, 52, 56, 57, 63, 89, 97], partly because video games have been notoriously sedentary in nature. Exergames promote physical activity while allowing players to take part in a fun video game, so using exertion to combat lack of activity and obesity is an obvious use of exergames.

Examples of exergames in this area include early camera-based games such as *EyeToy Knockout*, dance simulation games like *Dance Dance Revolution*, and some Nintendo Wii games. EyeToy games were made for the Playstation 2 game console and used a USB camera to display the player themselves in the video game (see Figure 2.10) [56]. *Dance Dance Revolution* is high in physical activity by making players press arrows on a ground mat with their feet in rhythm with the game (see Figure 2.11) [57]. *Wii Sports*, one of the best-selling video games of all time [99], lets players use a handheld input device, the WiiMote, as an extension of in-game objects. For example, it can be used as a tennis racket where players swing their arms as if they were playing real tennis (see Figure 2.12). These styles of games get players off the couch and moving their bodies in a variety of activities.

Figure 2.10: Screenshot taken from *EyeToy Knockout* [63].

Figure 2.11: *Dance Dance Revolution* being played [94].

Figure 2.12: Player performing a backhand shot in *Wii Sports* [93].

Research has shown that these games can be effective – although some studies have suggested that playing certain exergames is not intense enough to contribute towards the recommended daily amount of exercise for children [36].

Exergames have also been used in several other areas of physical abilities and behavior. Exergames have been designed to help with balance [8, 11, 16, 80], to help the elderly become more active [8, 16, 33, 96], and to improve the lifestyles of people with cerebral palsy [42, 43], Parkinson's disease [35, 44, 62], autism [27], and cystic fibrosis [76]. As an example, Hernandez et al. designed a novel exergame using a pedaling station input device to allow children with cerebral palsy to cycle effectively and reach recommended energy expenditure levels that were previously very hard to obtain [42]. Figure 2.13 shows different iterations the researchers went through to get the best pedaling interface for players with cerebral palsy.

Figure 2.13: Taken from [42]; different styles of chairs used in biking exergame designed to help children with cerebral palsy.

The rise of mobile technology has also influenced exergame research. Recent projects attempt to get people to exercise outside by playing games on their mobile phones [18, 19, 55, 58]. The mobile games created are effective for getting players outside, but obvious issues (such as running while looking at one's phone) must be addressed. To alleviate this problem, one study looked into using audio through the mobile phone to drive the exergame [17]. Instead of looking at one's phone, audio cues are given when they are performing certain actions in the game. Players are meant to run outside while the mobile phone is attached to them using an armband (see Figure 2.14). The game is narrated so players do not have to look at their phone while playing. The narrator guides them through a story, and the gameplay is based on keeping up a certain running pace chosen before the game starts. By removing the need to look at the mobile phone while playing, players can freely enjoy their surroundings and be safer while running outdoors.

Figure 2.14: Someone starting a game of *Time: Runner* from [17].

Although most research on exergames has considered some type of health effects, a second main reason for adding exertion to a game is to use physical activity as a design element. For example, physical skills such as strength or dexterity, and interaction effects such as fatigue, can be used as part of the design of the game. Exercise can still be performed, but the health benefits of the exercise are no longer the focus. For example, RopePlus is a game where a rope is attached to a wall that shows a projected scene [109]; players have to swing the rope in different ways depending on the game (Figure 2.15). The focus of the game is not to get exercise (although it is tiring to swing the heavy rope for extended periods of time) – instead, the goal is to have fun in a unique way.

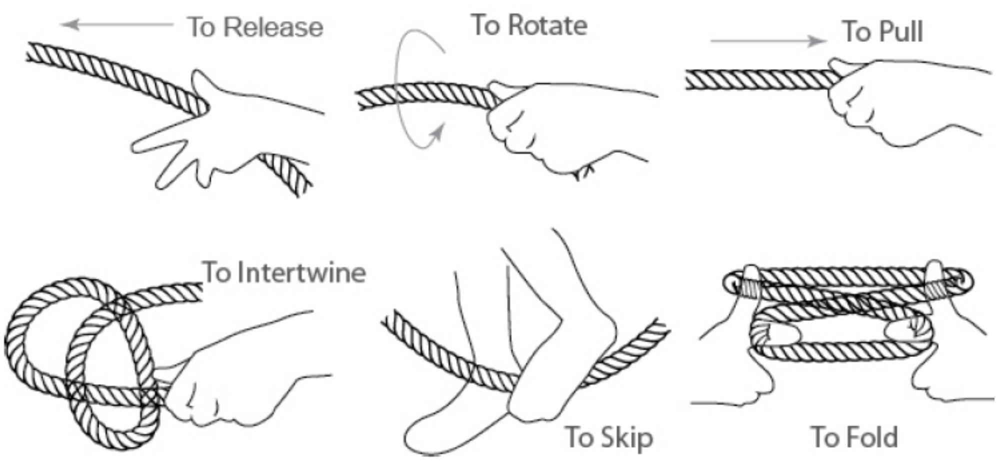

Figure 2.15: Different ways of using the rope in RopePlus [109].

Another game called "augmented climbing" uses projected graphics to create a game out of a climbing wall [50]. Players move up a regular rock climbing wall, which causes fatigue, and play a game at the same time. Duel reality (Figure 2.16) is another game where two players wear sensors on their body and carry mock swords. The goal is to dodge the other player's swings while hitting the other player with your own sword [100].

Figure 2.16: Two players playing Duel Reality wearing intrusive input devices and taking up a lot of space [26].

Mueller, a leading researcher in this area, has created a number of custom exergames that bring players ‘over a distance’ closer together by having them play networked exergames. These exergames are usually in the form of sports [66, 67, 68, 69, 70]. Remote Impact [67] is an exergame where players have to punch, kick and slam into a mattress on which is projected the silhouette of a remote player. The harder the impact the player can create, the more points they receive (see Figure 2.8) [68].

Another example of a high-exertion full-body exergame is Hanging off a Bar [73]. Players must hang on a bar above a mat which has a river projected onto it. At certain times, a raft comes along the river; at this time, players can drop down onto the mat to get a short rest. Once the raft is out of the projection area, players must hang on the bar again. The goal is to stay on the bar as long as possible. This is an example of an exergame where players do not necessarily move a lot, but they do experience a high amount of exertion.

Figure 2.17: Player hanging in Hanging off a Bar [73].

The design of games like Remote Impact and Hanging off a Bar requires high levels of exertion, and players need breaks in order to play for extended periods of time. In fact, the majority of exergames use full-body interfaces consisting of substantial amounts of exercise and fatigue. This led to researchers having to accommodate player fatigue by adding elements to their systems that are outside the games themselves – for example, providing rest breaks, or reducing the length of game sessions [66]. The full-body movements needed for most exergames also require that players have a large amount of free space around them to play. This is not how video games are traditionally played (i.e., using a standard controller and sitting in front of a display).

As one can see from above, exergames have become more like games that happen to use exercises rather than exercises that happen to use games. One limitation with current exergames is that there is little work focusing on fatigue as a design element in non-full-body interaction. If we take out the need for these games to use full-body movements, we could reduce the amount of fatigue to a sustainable level and also take up less space in the play area. The traditional game environment consists of people using a standard controller while sitting in front of a display. As described in later chapters, this research takes the growing field of exergames and comes up with a novel way to integrate it into the traditional game environment in order to make exergames more accessible.

2.3 COMMERCIAL EXERGAMES

Physical activity in commercial video games is now becoming common through the use of new input devices like the Nintendo WiiMote, the Microsoft Kinect, and the Playstation Move (see Figure 2.20). Several games make use of the capabilities of these devices for game mechanics such as swinging rackets or swords (e.g., *Wii Sports*, see Figure 2.12), or jumping (e.g., *Kinect Adventures*, see Figure 2.18). The *Mario & Sonic at the Olympic Games* title for the Wii uses physical control almost exclusively – for example, running events involve the player swinging both arms in a running motion as fast as possible. Other events like swimming are controlled in a similar fashion (see Figure 2.19)

Figure 2.18: Jumping action while playing *Kinect Adventures* [82].

Figure 2.19: Two players playing *Mario & Sonic at the Olympic Games* [23] with screenshot from the game [101].

Some sports video games also have an option to use physical controls (e.g., Madden football for the Wii). However, this mode of interaction has not been very profitable for the sports genre: for example, *Madden '08* sold triple the number of units for Xbox (i.e., non-physical control version) as it did for Wii (i.e., physical control version) [29]. Nintendo also introduced their

"All-Play" series of sports games in 2008 where all controls were physical. This series was not a market success, suggesting that sports gamers prefer traditional platforms and devices.

Figure 2.20: New video game input devices. Playstation Move on top, Nintendo Wiimote in middle, and Microsoft Kinect on bottom [88].

These commercial games are similar to previous exergame research in two ways. First, the physical activity involves large movements of the arms or legs – players must clear the space around them to play the game. Second, the activities generally involve short bursts of exertion rather than sustained effort – that is, quick-as-possible movements for a short amount of time that do not involve longer-term fatigue when done in isolation.

In contrast, this research focuses on *small-scale exertion*, which is defined as exertion that uses small movements and small muscle groups – for example, fingers, hands, and feet. Small-scale exertion has the advantage that it does not require a large space, and can be integrated into traditional game settings where people use standard controllers and sit in groups in front of a display.

There are very few examples of this type of exertion interface in current commercial games – but there are a few examples, some from the early days of sports video games, and some from current titles.

Mattel Football is a handheld video game made in 1977. The goal of the game is to get from one side of the screen to the other while dodging defenders. Movement in this game is controlled with three buttons; one button to move up one square, one button to move down one square, and one button to move to the side one square. The screen is a 9x3 grid of squares (see Figure 2.21). Defenders come at the player from the far side of the screen moving at their own pace; one square at a time. The player, however, can move as fast or as slow as they want; one square at a time. This allows players to press the three movement buttons at a fast and repetitive rate which leads to small-scale exertion. It is important to note, however, that players do have the option to slow down their button presses and even completely stop moving for certain amounts of time if the timing of the defenders is right. This enables players to play a small-scale exertion game for longer periods of time as compared to a game which needs constant button presses throughout the entire length of the game. This is one of the first cases of small-scale exertion in a sports video game [60].

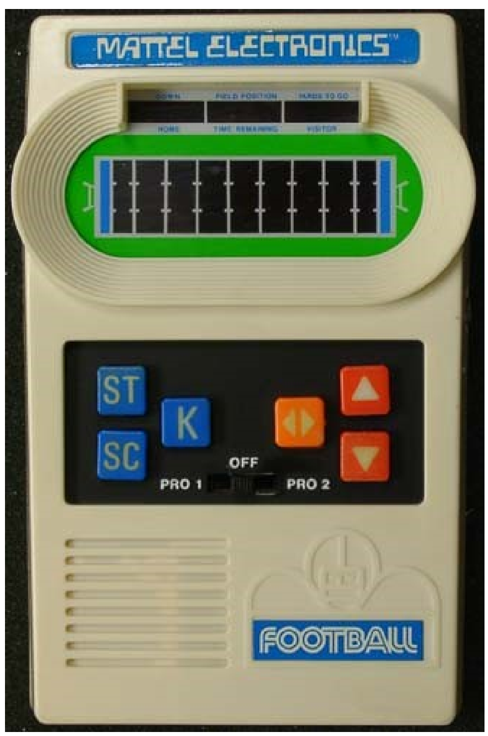

Figure 2.21: 1977 handheld sports video game *Mattel Football*. The three arrow buttons on the right side control movement [39].

In the 1980's, Olympic video games were starting to be created. For the most part, they included track and field events like the 100m dash and the long jump. The controllers for these early video game consoles only had a small number of buttons (e.g., two buttons on the Nintendo Entertainment System controllers; see Figure 2.22). Therefore, movement and jumping mechanics could only be designed in certain ways. The most popular mechanic was to alternate back and forth between two buttons on the controller to fill up a speed gauge. The faster the button presses, the higher the speed. This mechanic made sense as it was very hard to reach top speed and players had to practice to get better at the controls. However, players cannot maintain alternating buttons back and forth as fast as possible for very long. This caused most of the events in these types of games to be very short (e.g., less than 10 seconds long). One can think of these games as requiring quick-as-possible movements for short amounts of time. This type of small-scale exertion does not lend itself well to traditional sports video games where players play in game situations for extended periods of time (e.g., 10-40 minutes straight). Performing this control mechanic for extended periods of time could lead to soreness or even serious injury.

Figure 2.22: Controller for the Nintendo Entertainment System used for early Olympic style video games [102].

The early versions of Olympics-style games have also led to some similar modern games, such as the "Olympic Games" series for the Xbox and Playstation platforms. Unlike the Wii version, players can control the game with a standard controller. Running a race in *Beijing 2008* involves pressing two controller buttons back and forth as fast as possible (much like the original 1980s games discussed above). Interestingly, a newer game in the series (*London 2012*) changed the control style so that races are not as fatiguing: instead of pressing as fast as possible, the player must maintain a rhythm in their presses making it much less fatiguing. This control scheme requires little to no exertion.

2.4 FATIGUE, MOTOR SKILLS, PRACTICE, AND MOTIVATION

Fatigue is the acute impairment of performance which increases the perceived effort needed to perform a force and, in time, degrades the ability to produce the force. A review on muscle fatigue shows four themes for the systematic study of fatigue: task dependency, force-fatigability relationship, muscle wisdom, and sense of effort [25]. Task dependency is the idea that the context of the task determines which mechanism will be used to produce the fatigue. This also implies that fatigue does not happen through a single mechanism, but can be the result of a number of different factors. Force-fatigability relationship refers to the concept that a higher force will produce higher fatigue. Muscle wisdom is the idea that the force a muscle produces declines faster with constant stimuli rather than gradually decreasing stimuli. This point has since been questioned as a main activation strategy of fatigue [6]. The last is sense of effort, in which a person perceives that more force is needed than what is actually necessary. Physiological research has also shown that different muscle types (e.g., "fast-twitch" vs. "slow-twitch") fatigue at different rates [3], that there is high variability (across muscle groups and individuals) in the ability to recover from fatigue [61], and that fatigue can occur peripherally (i.e., due to processes in the muscles themselves) or centrally (usually involving exhaustion more generally).

A motor skill is a voluntary pattern of movement acquired through practice that is used to complete a task [49]. Motor skills can be divided into two groups: gross motor skills which involve coordinated movement of large muscle groups, such as when jumping; and fine motor skills which involve moving smaller muscle groups such as fingers or feet. Early research in the area of motor skills led researchers to believe that each person had a certain capability to move and that this capability generally worked the same for all motor skills. Recent research, however, suggests that there are many different motor abilities (possibly more than 100) which are independent from each other and that certain skills may involve many of these abilities at once [86].

A critical aspect of motor skill is that it can be improved through learning. Schmidt and Lee list four important characteristics for motor learning:

- learning is a process of gaining capabilities to become more skilled;
- learning directly comes from practice and experience;
- we are not able to observe learning directly, we can only infer that learning has occurred by observed behavior change;
- and learning seems to produce permanent changes in the capability for skilled behavior [86].

Most motor-skill learning is achieved through practice. There is a large body of research dedicated to practice in many areas (e.g., sports, cognitive skills, motor skills). Most of this research shows that learning follows the power law of practice: people gain a lot of expertise at the beginning, and then steadily the gains start to diminish in size over time [86]. This is the dominant viewpoint of practice gains, although there has been research arguing that an exponential law is more accurate [41].

Motivating people to practice to their full potential is an important factor of motor learning. One way to motivate people is by goal setting. Research is mixed, but there is evidence that vague 'do your best' goals are less effective than concrete goals such as 'try to beat 10 seconds' [86]. All of these factors were first studied using gross motor skills, but research has shown that they are also true for fine motor skills – fine motor skills improve with practice just as gross motor skills would [86]. However, there is still contention about exactly how skills improve through practice [37]. Another method of motivation is giving knowledge of results or knowledge of performance. Knowledge of results is feedback about the outcome of a movement in terms of the goal (e.g., giving the distance a golf ball is hit). Knowledge of performance is feedback given on how to improve one's performance (e.g., giving hints on how to swing a golf club better) [86].

There has been some neurophysiological research which focuses on fine motor skills and fatigue. Most importantly for this research, there is previous work into hand and finger fatigue which displays EMG [21] and fMRI data [53]. However, we do not see much research pertaining to hand and finger fatigue in the human-computer interaction field. One place where we do find fatigue of this nature is video games, but reported cases are rare and usually negative.

There has been one recent review of video game related injuries which spans from the beginning of the original Nintendo (i.e., early 1990's) to the present discussing case studies [48]. Back when video game consoles were first arriving into people's homes, the term 'Nintendinitis' (or 'Nintendonitis') was coined. Doctors around the world were getting cases of people's thumbs getting sore and they sometimes attributed this phenomenon to playing video games too much [10, 14, 51, 54, 87]. Other specific cases produced the terms Nintendo epilepsy [40], Nintendo neck [64], and Nintendo elbow [12]. One game that was thought of as causing too much exertion on players' hands was *Mario Party* for the Nintendo 64. This well-known game was notorious for breaking game controllers because players would be so rough with them; most notably, using the palm of their hands to swirl the joystick in circles as fast as possible. This caused its own problems, in the form of blisters (see Figure 2.23) [108]. Even the newest video games are causing injuries which are being documented. The terms 'Wiiitis' [7, 9, 13, 84] and 'Wii knee' [4, 46, 82] have been used in research articles describing recent video game injuries caused by newer video game consoles which will be discussed below. There has even been complete loss of sight in the eye of a video game player [81]. These negative fatigue-based injuries are rare, and in most cases can be fixed using rest or small doses of anti-inflammatory medication [48].

Figure 2.23: Blister on palm of hand due to swirling the joystick too much in the Nintendo 64 game *Mario Party* [20].

Instead of looking at video game fatigue as a negative, we try to focus on the positives that exertion and fatigue can produce when introduced to a video game. There has been a recent push to see exertion and fatigue as positives in the area of video games by the use of exergames. Our research tries to compliment this area by not using full body exertion, but instead, use the traditional game environment to produce small-scale exertion.

2.5 LIMITATIONS OF CURRENT SPORTS VIDEO GAMES AND ELECTRONIC SPORTS

As noted in Chapter 1, sports video games are very popular. Currently, they use advanced graphics, have all of the professional athletes available as characters in the game, and use the most realistic physics engines as possible to give the player a real sense of controlling their favorite real-world team or athlete. In contrast, when video games were first becoming widely available, they did not have the high-end graphics or realistic physics engines we have today. Back then, they had to rely on challenging a player’s reflexes, timing, and physical skill with the input device. At that time, sports video games were all about timing and pressing buttons faster and more precisely than the computer opponent or other player. *Mattel Football* was a handheld video game released in 1977. The player used arrow buttons to move the character and dodge moving obstacles. This game uses small-scale exertion because it requires quick button presses. Since graphics and technology as a whole have only been getting better, it is no surprise that game companies would focus more on the realistic simulations that we see today.

However, we feel that the sports video games currently available have three drawbacks that can be addressed. The first drawback is the lack of expertise development in simple skills like running. If a character is on a breakaway in a sports game and that character has higher in-game statistics than the other characters chasing him, there is no way to stop the breakaway. This is not because the player on the breakaway is a better player; it is solely because the character the player is controlling has a higher speed. If a game is based on competition between player skill, there should be a way for a more experienced player to catch up to a lesser experienced. The second drawback is that common actions like passing and shooting are carried out very much the same by any player. In the NBA basketball video games, players can simply press the pass button on the controller to make a perfect pass to another character on their team. They do not even have to hold a general direction to pass to, just pressing the pass button alone will figure out a close character to pass the ball to, and usually make a perfect pass to them. The point is, two players cannot simply press a single button in different ways. Shooting is much the same, simply hold and release the shoot button to shoot the ball. The most impacting variable that goes into the successfulness of a shot is the in-game character's shooting statistic. The final drawback is the absence of fatigue. Real sports are heavily based on fatigue, but traditional video games can be played for hours on end without affecting the player's physical endurance. Sports video games have had these drawbacks for decades and yet all major sports genres release a new game every year, and people still buy them even when there are only minor improvements from year to year (e.g., updated roster and improved graphics).

Despite the popularity of sports video games, there is little research on the genre. One large study was performed in 2012 to find out who plays sports games. An online survey asked 1718 participants what kind of players play sports video games and their habits concerning sports in general. The survey found that 98.4% of sports video game players are males, mostly in their mid-20s. The study also supported a widespread belief that sports gamers are also sports fans with 93.3% self-identifying with this statement [91]. Research has also shown that playing sports video games can improve performance in the real-world sport counterpart [22]. In addition, previous knowledge of a sport can affect success in playing sports video games [59]. This research also states that not much work has been performed concerning individual differences, and this is an area that should be further explored.

Electronic Sports (eSports) is another area that has recently gained popular attention – eSports are professional sport-like competitions using video games that are broadcasted over the Internet [5]. These competitions are much like real sports, in that players train, gain expertise, and compete at high levels. Some research in the area of eSports is about new interaction techniques to help with high-level performance [38], and different broadcasting techniques to showcase the competitions [5]. The most common genres played professionally are multiplayer online battle arena, real-time strategy, fighting games, and first-person shooters [104]. There is little to no recognition of sports video games being included in the area of eSports. This seems very counter-intuitive; why are sports video games not a good fit for eSports? We believe it is because of the drawbacks already discussed. These drawbacks make it so sports video games are not inherently sport-like or competitive in a completely balanced manner. eSports competitions are about showcasing one player's (or a team's) skill level over another. Sports video games rely too much on in-game character statistics and automatic shooting/passing algorithms to be a balanced competition of player skill and to be involved heavily in eSports. Professional eSports players have recently been officially granted 'professional athlete' status by the U.S. government in order to obtain visas to play in the U.S. [31]. There are also full scholarships, comparable to athletic scholarships, which major universities in the United States offer to eSports players [28]. Therefore, there is definitely a comparison to real-world professional athletes and eSports players. Unlike traditional sports video games, the small-scale exertion game invented for this thesis (Jelly Polo) would fit well as an eSport, because it allows training, teamwork, and high levels of competition solely based on player skill.

This background information gave us the knowledge we needed to move forward with creating two of our own small-scale exertion games. We took ideas from earlier video games, to begin with, and eventually created a well-rounded small-scale exertion game that can be played for extended periods of time, while still using exertion as a game design element. The chapters below discuss the creation and evaluation of these games.

CHAPTER 3

INITIAL EXPLORATION INTO A SIMPLE SMALL-SCALE EXERTION GAME

In this chapter a simple game is introduced which uses small-scale exertion – Track and Field Racing (TaFR). This initial attempt at a small-scale exertion game was meant to be the simplest form of small-scale exertion possible to investigate basic effects on individual abilities and fatigue. In this chapter we describe the TaFR game and an initial study looking at whether small-scale exertion can increase the amount of individual difference between players, and can make fatigue a factor in gameplay.

3.1 GAME DESCRIPTION

The first game we created using small-scale exertion, TaFR, is based on the Olympic video games discussed in Chapter 2. Specifically, we used the running race implementation used in many Olympic-style games like *Track and Field* for the Nintendo Entertainment System. For this first attempt, we wanted to use the simplest form of small-scale exertion that has been used in the past. TaFR was used as an initial test to determine whether small-scale exertion did in fact lead to individual differences and fatigue.

TaFR was built using Processing which is a programming language based on Java [77]. Processing is commonly used as a visual programming tool because it is easy to draw shapes and colours on the screen. We used Processing to quickly build a simple game that took keyboard input to move the objects on the screen. The gicentreUtils library for Processing [34] was also used to display graphs of player performance.

TaFR is a simple game where two players race against each other at the same time using the same keyboard (Figure 3.1). In a TaFR race, two players run from a start line to a finish line; TaFR is an example of a parallel exergame because opponents do not interact with each other during gameplay (Figure 2.9). To run in TaFR, players press two keys repeatedly with their dominant hand (player 1 uses the A and D keys; player 2 uses the left and right arrow keys). The faster the player presses the keys, the higher the player's power bar rises, and the faster the in-game character runs.

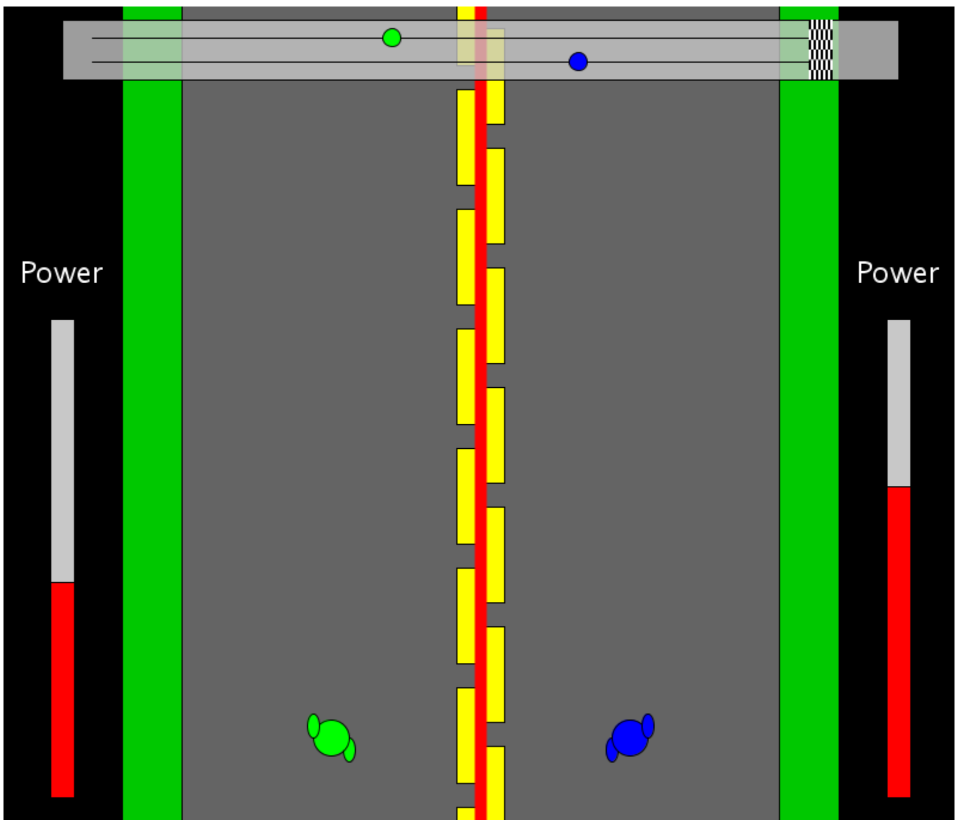

Figure 3.1: Track and Field Racing (TaFR) race in progress.

The power bar has an upper limit, and decreases when the keypress rate drops, or when the keys are not pressed in alternating order. To run fast, players must consciously work to alternate fingers at high speed; this repetitive action causes fatigue. The game also shows a distance chart overlay at the top of the screen showing how far the characters are from each other and how far from the finish line they are. The main screen of the game is split, and therefore the characters do not move vertically during the race; only the road marks in the middle of the screen move. This makes the distance chart at the top of the screen important for the players to know where they stand in the race.

Once one of the players crosses the finish line, a results screen is displayed. This screen displays the outcome of the race and performance graphs (which are explained in more detail in section 3.2.4).

3.2 STUDY METHODS

3.2.1 Participants

Eight participants (1 female, 7 male) were recruited from the HCI Lab at the University of Saskatchewan, who were between 22 and 32 years old (mean 25.6). Three participants had played physical games before (e.g., *Wii Sports*, *Dance Dance Revolution*, etc.), one participant played sports video games regularly (~1 hour per week), three participants played real-world sports on a regular basis (3+ hours per week), and participants played an average of 8 hours of console and computer video games per week. We recruited from our lab for convenience, but because we were only looking at low-level effects of exertion, there is little likelihood of any participant bias.

3.2.2 Apparatus

The study used custom software built in Processing (Java-based programming language) using the gicentreUtils library and ran on a Core i3 Windows PC using a 23.6 inch Asus monitor. Participants sat side-by-side in front of the monitor using their dominant hand on a Microsoft keyboard.

3.2.3 Procedure

Three double-elimination tournaments were run for the study: one with short races (simulated 100m race), one with medium races (simulated 200m), and one with long races (simulated

400m). There were two brackets in each tournament. Each player started the tournament in the top bracket. Double elimination means that if a player wins, they move on to the next round and stay in the top bracket. If they lose once, they move down to the bottom bracket. If they lose for a second time, they are eliminated. Appendix A.2 shows the tournament brackets used.

The same eight participants described above ran in all three tournaments. Each participant ran between two and seven races for each tournament. Races were held one after another so participants did not have much time to recover; there was a five-minute break between races. For the first tournament (100m) the eight participants were randomly entered into the brackets. Performance in the 100m race determined seeding for the subsequent tournaments.

3.2.4 Measures

For each race, we kept track of the time between keypresses, the power level (i.e., from the in-game power meter) over time, and incorrect keypresses. We also kept track of race times, each player's keypress rate, and each player's average power level. At the end of the race, this information was displayed for the players in graph or text form (see Figure 3.2).

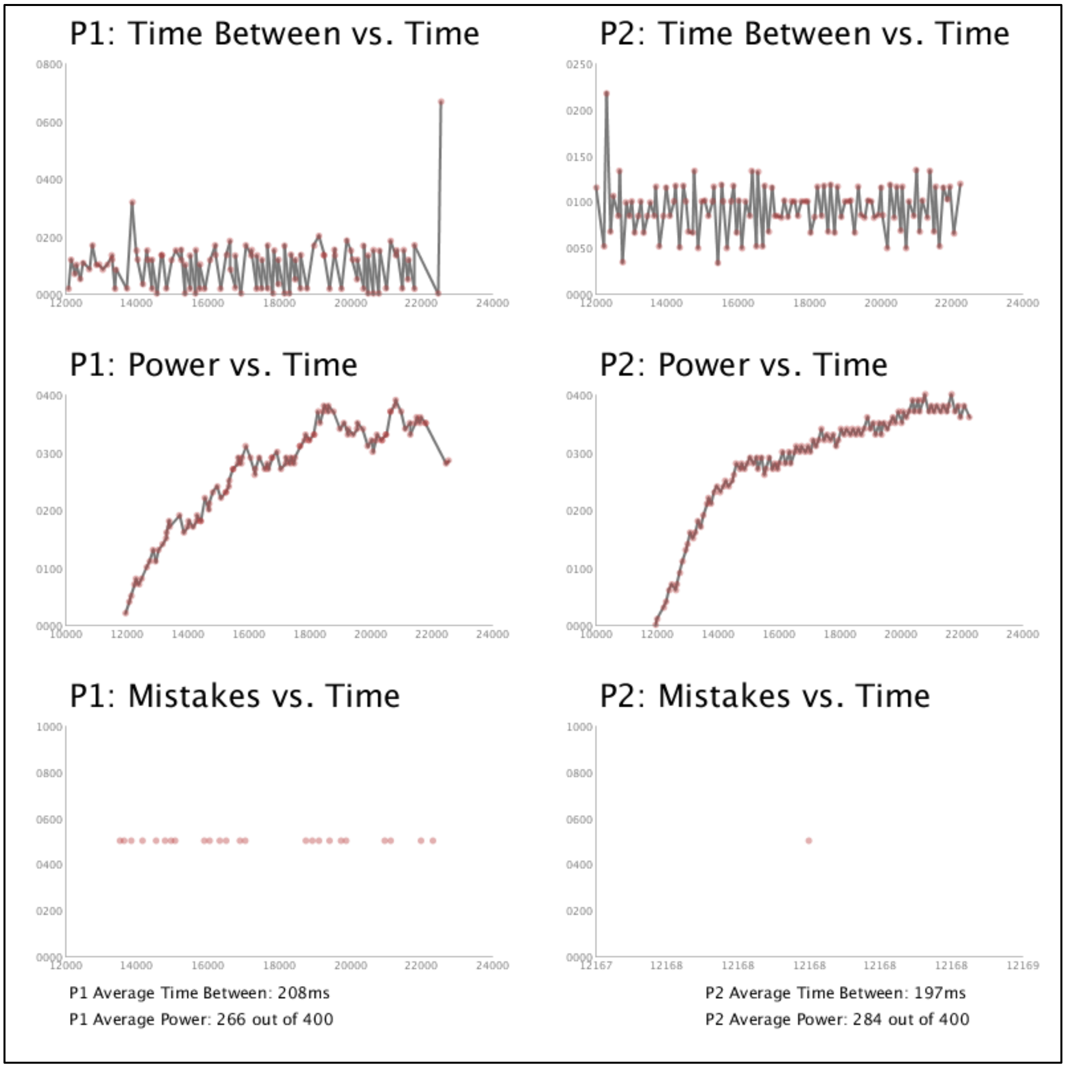

Figure 3.2: TaFR race results screen. 'Time Between' means the time between alternate key presses. 'Mistakes' refers to when players do not alternate key presses and press the same key twice in a row.

3.3 RESULTS

TaFR was used to investigate two issues: whether physical control over running led to individual differences in ability and to changes in performance over a race due to fatigue. Expertise development was not looked at because players would have to play for longer periods of time to be able to observe any kind of increase in skill. The control scheme used and the information gathered were well-suited for a quick short-term study. We did not want to cause any injuries and therefore did not gather expertise development information.

3.3.1 Movement and Ability Differences between Players

Table 3.1: TaFR results

Race Length	Overall Average Time Between (ms)	Minimum Average Time Between (ms)	Maximum Average Time Between (ms)	Overall Average Power	Minimum Average Power	Maximum Average Power	Percent Variability of Time Between (%)	Percent Variability of Power (%)
100m	98.75	81	147	251.68	48	328	12.2	24.9
200m	99.75	81	133	276.11	139	353	9.5	17.7
400m	111.86	93	168	248.64	135	343	10.7	18.6

Table 3.1 shows results for time between button presses and power for each race length. Players' running power over time was also recorded – Figure 3.3 shows four results from the 100m race. As the charts show, people performed very differently in terms of several characteristics: acceleration, top speed, and consistency. For example, player A had faster acceleration and a higher top speed than player B (row1 of Figure 3.3). Player C had the fastest top speed of all the players, and was also able to hit the maximum power possible in the game (row 2).

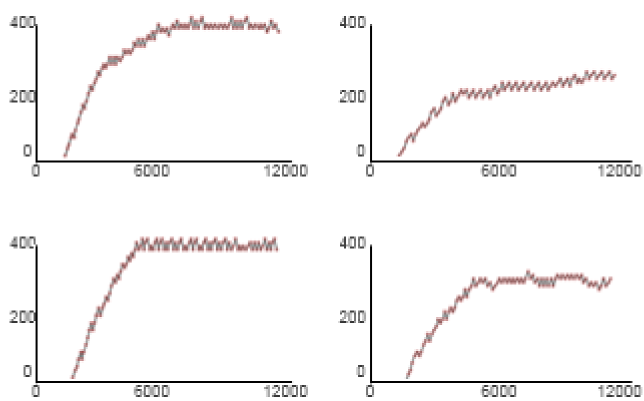

Figure 3.3: Power-over-time charts for two 100m races.

The performance differences arose both from basic differences in the physical capabilities of the players (finger speed and coordination) and from the amount of effort put into the race. The best players (e.g., Player C) could press the two-key sequence faster, could maintain a high press rate without losing coordination, and could continue at that high rate for the entire race. However, performance also depended on effort, in that players had to work hard to win races against opponents who had similar physical abilities.

3.3.2 Changes in Performance during the Race

Figure 3.4 shows power-over-time charts from three additional races: 100m in rows 1 and 2, and 400m in row 3. These charts clearly demonstrate that players' performance changed over the course of a race (sometimes dramatically), due to fatigue or a desire to conserve energy (i.e., players may have purposefully slowed down their speed in order to save energy later in the race).

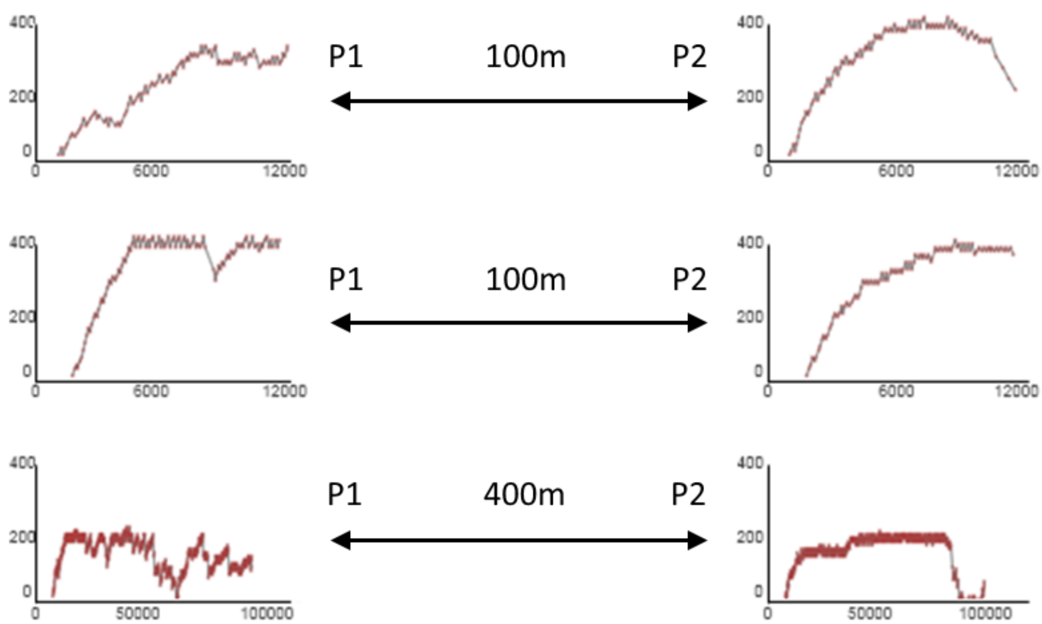

Figure 3.4: Power-over-time charts for three example races between P1 and P2 (100m, 100m, and 400m).

In the 100m race (Figure 3.4, row 1), player 1 (left) is well behind the entire race because player 2 (right) can 'run' faster, with better acceleration and a higher top speed. Near the end of the race, player 2 slows down (falling power line) because he is so far ahead that he does not need to expend much effort to win the race.

In the second 100m race (row 2), player 1 (left) moves into an early lead, but partway through the race, becomes tired and has to rest his fingers (sharp dip in the power line). Player 2 (right) has been steadily increasing her speed, and so catches player 1. The approach of player 2 prompts player 1 to expend more effort again to match the increasing speed of the other runner. (Player 1 wins).

The 400m race (row 3) shows an extreme case of an early leader becoming fatigued and losing the race. Player 2 (right) had a substantial lead coming into the final part of the race – but then his fingers 'gave out' from fatigue (power line drops to near zero). Player 1 (left), who had been much less consistent, made a final dash, passing player 2 near the finish line.

3.4 DISCUSSION

The episodes described above clearly demonstrate that physical controls – even something as simple as two-finger key pressing – can lead to considerable complexity in the way a race plays out. In particular, fatigue becomes an important factor in the race: players must conserve energy, must 'dig deep' to finish the race strongly, and can encounter catastrophic collapses that dramatically change the race's outcome.

We initially found that physical controls added complexity of the gameplay and made a major difference in the play experience. In TaFR, physical control over running made an extremely simple system into a fun and challenging contest. The changes in races over time, and the last-minute reversals that occurred, added a level of interest that clearly aided the gameplay.

However, we do want to point out that it is important to consider the potential drawback of physicality in game controls in a system like this. As described in Chapter 2, this game is made up of short bursts of quick-as-possible movements. Performing this fatiguing action for extended periods of time could, and most likely would, cause injury if overused. Even in our brief experience, we saw sore wrists and hands after longer races. The soreness observed quickly went away for the participants, but this issue may stand in the way of commercial adoption of this movement control scheme.

In TaFR, physical control over running made an extremely simple system into a fun and challenging contest. The changes in races over time, and the last-minute reversals that occurred, added a level of interest that clearly aided the gameplay. TaFR does go further in terms of fatigue levels than most commercially available games would, but it did show the effectiveness of the small-scale approach to exertion – and we built upon these lessons in a more realistic game called Jelly Polo discussed in the Chapters below.

CHAPTER 4

A STUDY OF THE EFFECTS OF ADDING SMALL-SCALE EXERTION TO A SPORTS VIDEO GAME

Chapter 3 was a successful and promising look into how small-scale exertion affects gameplay. Because of this, we decided to create a more traditional game that uses small-scale exertion for its controls; that game was Jelly Polo. The study with TaFR showed that small-scale exertion allowed for differentiation between players and that this exertion caused fatigue, which increased the overall unpredictability of the game. However, we wanted to develop a new game for two reasons. First, the fatigue effects in TaFR would not be reasonable in a commercial video game because of the risk of injury due to the control scheme. Second, we also wanted to find ways of adding more expertise development into games (TaFR may have allowed for eventual expertise development, but injuries could have occurred if we spent too much time with the game).

The second study explored the use of physical controls in a more traditional sports video game in order to provide qualitative data on expertise development, individual differentiation, and fatigue. As will be discussed below, it is suggested that Jelly Polo is a potential solution to all three problems stated in the Chapter 1 (i.e., expertise development, individual differentiation, and fatigue), thus making a more competitive and sport-like game.

4.1 GAME DESCRIPTION

Jelly Polo is a top-down 2D sports video game where two teams of three players compete to put the ball in the opposing team's net. Jelly Polo is an object-based, non-parallel competitive exergame because players directly compete against each other to control possession of the ball (Figure 2.9). The two teams play in a collocated area, side-by-side, and share the same screen. Jelly Polo is very similar to hockey or soccer. When the game starts, or after a goal has been scored, there is a faceoff in the middle of the screen where the ball (re)appears. Unlike most traditional sports, there are no set positions in Jelly Polo; players are free to move their character anywhere in the play area (i.e., no player has to only play goalie or any other set position). Players have control over only one specific in-game character each; there are no switching characters or line changes. The play area is contained by the edges of the screen. The only area players cannot access is the opposing team's crease (see Figure 4.2). The crease is a semi-circle located directly around the teams' nets. For every goal that is made, that team gets one point added to their score; when the game ends, the team with the most points wins.

Figure 4.1 shows the layout of the version of Jelly Polo used in this study. The scores are shown at the top of a black background. Characters and the game in general are meant to look like jellyfish playing underwater. Figure 4.2 is a close-up of Jelly Polo annotated for more clarity. Jelly 5 has the ball and is moving toward the other team's net. The bubble trail shows the direction of movement. Jelly 5 is also holding the ball away from the incoming defender (Jelly 6) and the goalie (Jelly 4). The defenders (6 and 4) hold their arms out in an attempt to steal the ball or save a shot. Arm position is independent of player movement. A YouTube video showing Jelly Polo gameplay can be found here: https://www.youtube.com/watch?v=D_lQyCjRlQU

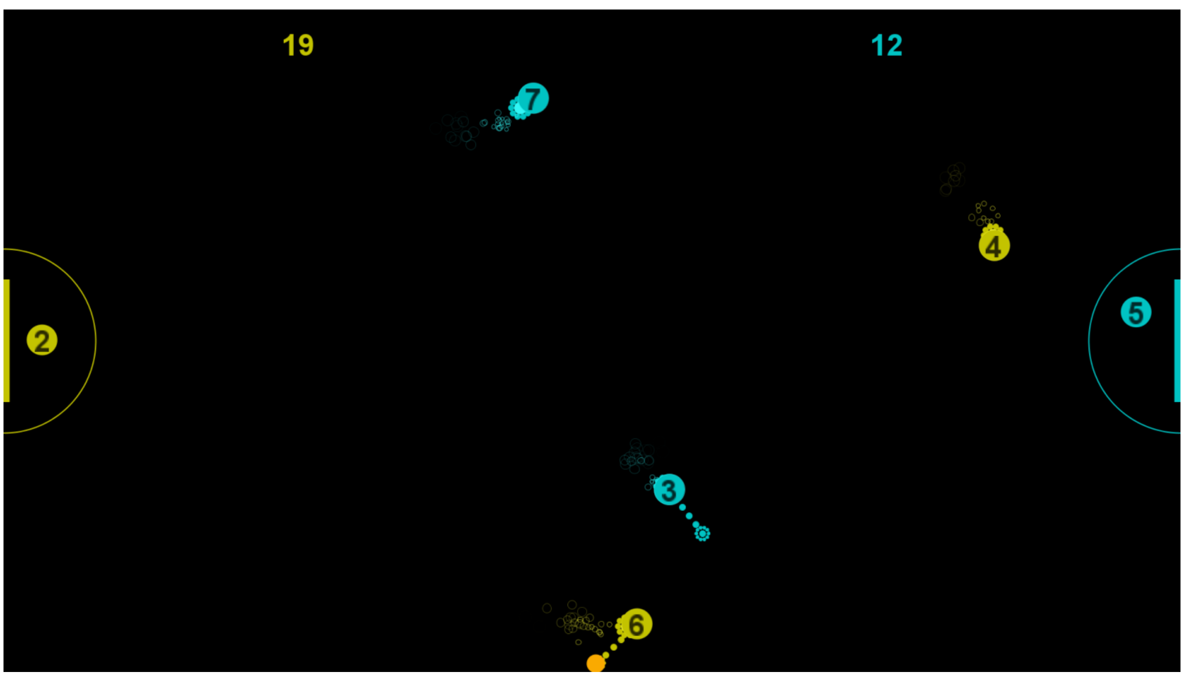

Figure 4.1: A game of Jelly Polo in progress.

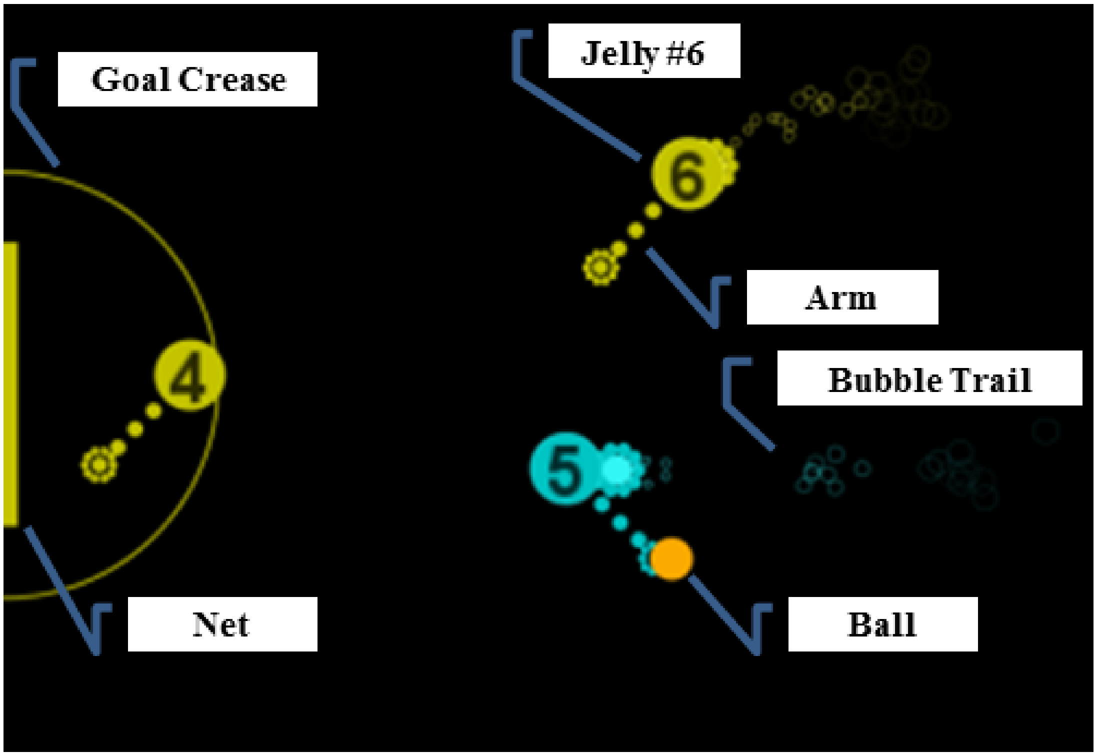

Figure 4.2: Jelly Polo close-up with annotations.

Jelly Polo was built using Processing [77]. We used the Procontroll library [78] so Processing could handle traditional controllers as input. Jelly Polo is a very simplistic looking game, using only circles and numbers, but the minimalistic look allowed players to focus on the gameplay instead of the graphics.

4.2 GAME CONTROLS

The main feature of Jelly Polo is the control scheme. Traditional sports video games, as discussed in Chapter 2, use rate-based movement and automated passes and shots. This control scheme does not allow for expertise development, in terms of speed; lowers the chance for individual differentiation; and does not introduce fatigue into games. Jelly Polo, on the other hand, uses impulse-based movement and precision throwing. Impulse-based movement is where each push, or flick, of the left thumbstick on a traditional game controller represents a single impulse, with the amount of displacement providing the magnitude value, and the 2D position of the thumbstick providing the direction. Controller thumbsticks automatically return to the centre, allowing the next impulse to be initiated immediately. This requires players to repeatedly flick the left thumbstick in the direction they want their character to move; a bigger flick results in a bigger impulse. There is no limit to speed, other than the human limitations on operating the controller.

Precision throwing requires that the user control two values: direction and distance. The properties of the thumbstick can be mapped to these values (2D position to direction, and displacement speed to distance), and so the second thumbstick of the game controller was used to control the character's arm. The arm is used to pass, shoot, steal, deke, and make saves. We used a threshold-based release mechanism so the ball can be thrown without an explicit release switch. The threshold-based release mechanism was also beneficial so players could hold out the ball without throwing it in order to maneuver the ball, or 'deke', around other players. Precision throwing required players to use precision for passes and effort for hard shots, which is not seen in traditional sports video games.

4.3 STUDY METHODS

In order to evaluate a well-rounded traditional sports video game using small-scale exertion, a long-term study was carried out with four consistent teams of three. It was important to keep teams consistent so they could gain teamwork and strategies together over time as a real-world sports team would. The long-term nature of the study was to be able to qualitatively observe expertise development, individual differentiation, and fatigue.

4.3.1 Participants

For this study, we had 12 participants (4 teams of 3, 10 male and 2 female). Participants ranged in age from 19 to 36 (mean 25.3), and were recruited from within our research lab. Participants were used from our lab because we needed to maintain consistent teams across the month-long study, because we wanted teams to become familiar with each other and discuss strategy between games, and because of the large time commitment (11 play sessions plus several interviews, totaling more than eight hours spread over the month).

Three participants played real-world sports on a regular basis (more than 3 hours per week). All participants had gaming experience (mean 11.7 hours per week), although only two participants played sports video games regularly, and only half had played games with physical controls (e.g., *Wii Sports*).

4.3.2 Apparatus

The study used custom software built in Processing [77] using the Procontroll library [78] (see section 4.1) for handling controller input, and ran on a Core i3 Windows PC using a 23.6 inch Asus monitor. A Microsoft keyboard was used before each game to calibrate the controllers and to output log data during halftime of each game. Six identical Logitech Dual Action Gamepads were used for the controllers (see Figure 4.3). The controllers were connected into the PC's USB ports. Participants sat side-by-side in front of the monitor grouped by team. A Canon HG10 AVCHD high definition camcorder attached to a tripod behind and above the players was used to video record all play sessions. A Samsung Galaxy S3 mobile phone was used to time each game using the default stopwatch.

Figure 4.3: Logitech Dual Action Gamepad; the controllers used for Jelly Polo.

4.3.3 Procedure

We ran a four-week Jelly Polo league with four teams. The twelve participants were split up into teams using a random number generator. Each team played three games a week, one every Monday, Wednesday, and Friday. See Table 4.1 for the schedule of each week. After the first two weeks there was a one-week break due to participants going on holiday. After the break, only one more week of games was played. After the Jelly Polo league games were played, we ran a short playoff series. In the first round of playoffs, the first-place team played the last-place team and the second and third-place teams played each other in a single elimination game. The winners of those games played each other in a best-of-three playoff final. Eighteen games were played in total (nine for each team) during the league and four games were played during playoffs (the best-of-three series ended in two games).

Table 4.1: Jelly Polo weekly game schedule.

	Monday	Tuesday	Wednesday	Thursday	Friday
Game 1	Team 1 vs. Team 2	No Games	Team 1 vs. Team 3	No Games	Team 1 vs. Team 4
Game 2	Team 3 vs. Team 4	No Games	Team 2 vs. Team 4	No Games	Team 2 vs. Team 3

Each league game, and the first round of playoffs, was played in two 10-minute halves. Each game in the last round of playoffs was played in two 15-minute halves. The halftime break would vary between 2-5 minutes. Before each game started, the video camera was turned on and each participant had to calibrate their controllers. This involved them moving to one side, and then holding their arm out to one side as someone used the keyboard to calibrate them. This step was necessary at the time because some controllers would be inverted upon starting the game. Once everyone was set up, the game began. The conductor of the study facilitated the halftime break which would only start after a goal; goals came frequently so no halves waited much longer than their allotted times. Players were allowed to do whatever they wanted during halftime (including move their characters around) but were directed not to touch the ball as the game kept running during the halftime break. The games were restarted after halftime by the experimenter counting down from three. The teams switched sides after halftime, similar to many real-world sports. This was to make sure both teams had an equal amount of time facing either direction on offense/defense. Once the second-half time limit was reached, the conductor waited for a goal to stop the game. If the score was tied after this, the teams played until the next goal was scored; this ensured no games ended in a tie.

4.3.4 Measures

Typical sports statistics were kept for each game. This included Shots, Goals, Assists, Saves, Steals, Own Goals (i.e., scoring on your own net by accident), Passes, Faceoff wins, and Turnovers. The final score for each game was also recorded. Some statistics were able to be handled by game logging (goals, own goals, final score) but all other statistics were gathered by video analysis. This was due to the difficult nature of automatically logging certain stats. Shots and passes were specifically difficult to log. For example, a shot usually travels towards the opposing team's net. However, the shot attempt may hit the net, it may hit another player before getting to the net, or it may miss the net entirely, but it should still count as a shot. Passing has similar issues. A pass can be thought of as the ball going from one member of a team to another member of the same team. However, if one player attempts to shoot the ball and it bounces off the end wall and goes to a teammate, this should count as a shot, not a pass. These are just some examples where judgement using the video recordings for context would lead to more reliable data gathering. All statistics and team standings were made available online on a Google Document for all the players and interested parties to see. Comments made during the games were recorded by the conductor during the time of the game or during video analysis.

After the entire Jelly Polo league was completed, participants were asked to fill out a questionnaire. The questionnaire was a number of Likert-scale questions rating statements from 1-disagree to 7-agree, 4 being neutral. Table 4.2 shows the full set of Likert-scale questions asked in the questionnaire along with frequency results. The questionnaire also had a ranking question to determine which sport players thought Jelly Polo most resembled. The end of the questionnaire had fill-in-the-blank questions to determine if there was a consensus on certain players and teams (e.g., "Who was the fastest player" or "Which team did you not like to play against the most"). Appendix B.1 has the full questionnaire. After the questionnaires, each team was interviewed separately. The structured interview was audio recorded and asked the questions in Table 4.3.

Table 4.2: Jelly Polo post-league Likert-scale questions with frequency results (1=disagree; 7=agree).

Question	1	2	3	4	5	6	7
Jelly Polo was fun	0	0	0	0	2	3	7
Jelly Polo was frustrating	1	3	3	1	4	0	0
I looked forward to playing Jelly Polo on game days	0	0	0	2	3	3	4
I would enjoy playing Jelly Polo outside of the lab	0	0	1	0	4	4	3
Jelly Polo was physically tiring	0	2	1	3	3	2	1
Jelly Polo was mentally tiring	0	1	2	5	2	2	0
Jelly Polo made my thumb sore	0	0	3	2	4	2	1
I played more offense than defense	1	3	0	1	4	1	2
I passed more than I shot	1	3	3	0	0	4	1
I tried to win every faceoff	1	1	1	1	3	5	0
My team had a set strategy	0	2	1	0	3	6	0
I liked playing goalie	2	1	1	3	1	2	2
Jelly Polo is a sport	0	0	0	2	6	3	1
I knew which player was which number on my team	0	0	2	0	3	4	3
I knew which player was which number on the other team	1	3	0	2	3	1	2
I kept track of my stats	0	1	2	1	3	3	2
I kept track of my team's stats	0	1	1	3	2	3	2
I tried hard to be the top in a certain stat	1	4	0	0	1	5	1
I got better at Jelly Polo over time	0	0	0	3	2	2	5

Table 4.3: Jelly Polo post-league interview questions.

Question Number	Question
1	What was the best part about Jelly Polo?
2	What was the worst part about Jelly Polo?
3	Did your thumbs get tired playing?
4	What was your team's strategy? Did it ever change throughout the league or for different teams?
5	Did the thumb movement have an effect on your strategy?
6	Did which side you were on make any difference?
7	Did which color you were make any difference?
8	Did which number you were make any difference?
9	Did you get better at playing over time? How?
10	Did the week break have any effect on how you played afterwards?
11	Did you like having all the stats available?
12	Did having the stats available change how you played?
13	What did you think of each difference team? 1? 2? 3? 4?
14	Would you keep playing Jelly Polo? In the lab or outside the lab?
15	Did you play differently if you were winning or losing the game by a large margin?
16	Did you ever talk about Jelly Polo to anyone when the games weren't on? Who?

4.4 RESULTS

Jelly Polo games were fast, exciting, and active. Table 4.4 shows overall numbers of the recorded game statistics (Shots, Goals, Assists, Saves, Steals, Own Goals, Passes, Faceoff Wins, and Turnovers).

Table 4.4: Jelly Polo average-per game statistics

Statistic	Average-Per Game	Highest Statistic Achieved by a Single Participant in One Game
Shots	184	78
Goals	34	24
Assists	9	8
Saves	87	41
Steals	94	42
Own Goals	2	4
Passes	78	28
Faceoff Wins	35	24
Turnovers	94	37

The teams were highly competitive, and games were rousing and noisy affairs. In addition to the overall success of Jelly Polo as an entertaining game, we also observed behavior and events that support the hypothesis about small-scale exertion. The sections below report our observations of expertise development, individual differences, and changes in performance due to fatigue. We also briefly describe expressive communication shown by the players, and take an initial look into how gameplay in Jelly Polo changes when using traditional rate-based controls.

4.4.1 Expertise Development with Physical Controls

Player skills develop over time in all types of games – both in Jelly Polo and in more traditional sports. Here we focus particularly on the development of skill with the physical aspects of the game – impulse-based movement and precision throwing. We observed the development of several types of skills over the four weeks of the Jelly Polo league. Based on questionnaire results, 9 out of the 12 players stated that they had improved over time. In follow-up group interviews with each team, people discussed the ways in which they had seen improvement, and many of these areas were related to our interests in physical-based movement and passing:

- Movement – running speed, mobility (i.e., ‘deking’ around other players), ball handling (i.e., moving the jelly’s arm around to protect the ball), and goalie movement (i.e., how to best block shots);

- Passing and shooting – directional and distance accuracy in throwing the ball, learning to use the walls for bank passes, and mastering trick shots (e.g., fast shots, or shooting in a different direction to movement);

- Strategy – both individual strategies such as choosing the time to make a rush, when to shoot, or when to attempt a steal; and team strategies such as who would play forward or defense, how to set players up for passes, and when to switch goalies.

One person mentioned that their performance did not improve as much as others in one area (they were not as fast as other players), but that they learned other skills that helped to make up for that limitation.

As an example of skill in passing and throwing, Figure 4.4 shows a well-designed passing play (orange arrows indicate a pass, yellow arrows indicate movement, and the red arrow indicates a shot; red numbers indicate the order of the actions). In this play, Jelly 4 passes to 6 to keep the ball away from opponent 7. Then, Jelly 6 moves up with the ball, and Jelly 2 moves into position to take the pass; Jellies 3 and 5 move to intercept the ball carrier, leaving a lane open for 6 to pass to 2. With the defender and goalie out of place, 2 has an open-net shot.

Another example is diagrammed in Figure 4.5, in which one team completes a ‘bank pass.’ In this scene, the goalie (Jelly 7) has the ball. Opponents 4 and 6 rush him to try and steal it. Teammate 5, knowing that his team has clear possession of the ball, moves up field and sees that a bank pass is open. Before 4 and 6 can get to the goalie (7), he passes the ball off the wall and toward his teammate (5), leading to a breakaway.

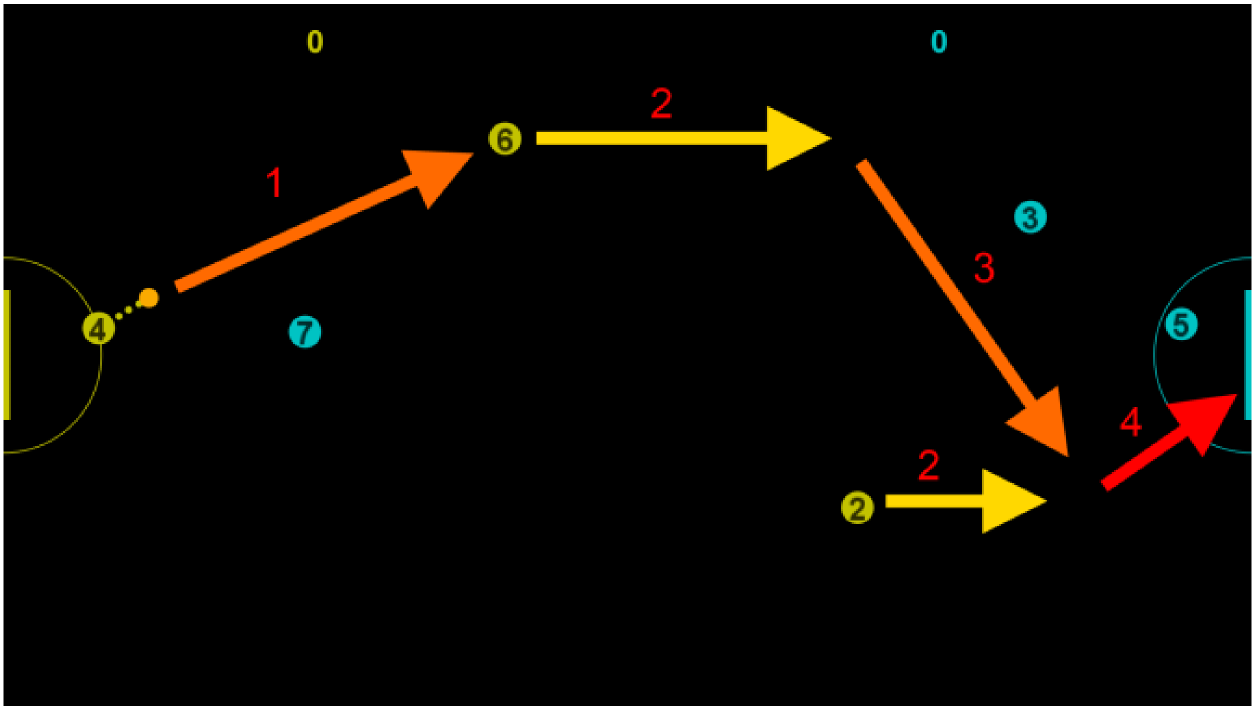

Figure 4.4: 'One-timer' passing play.

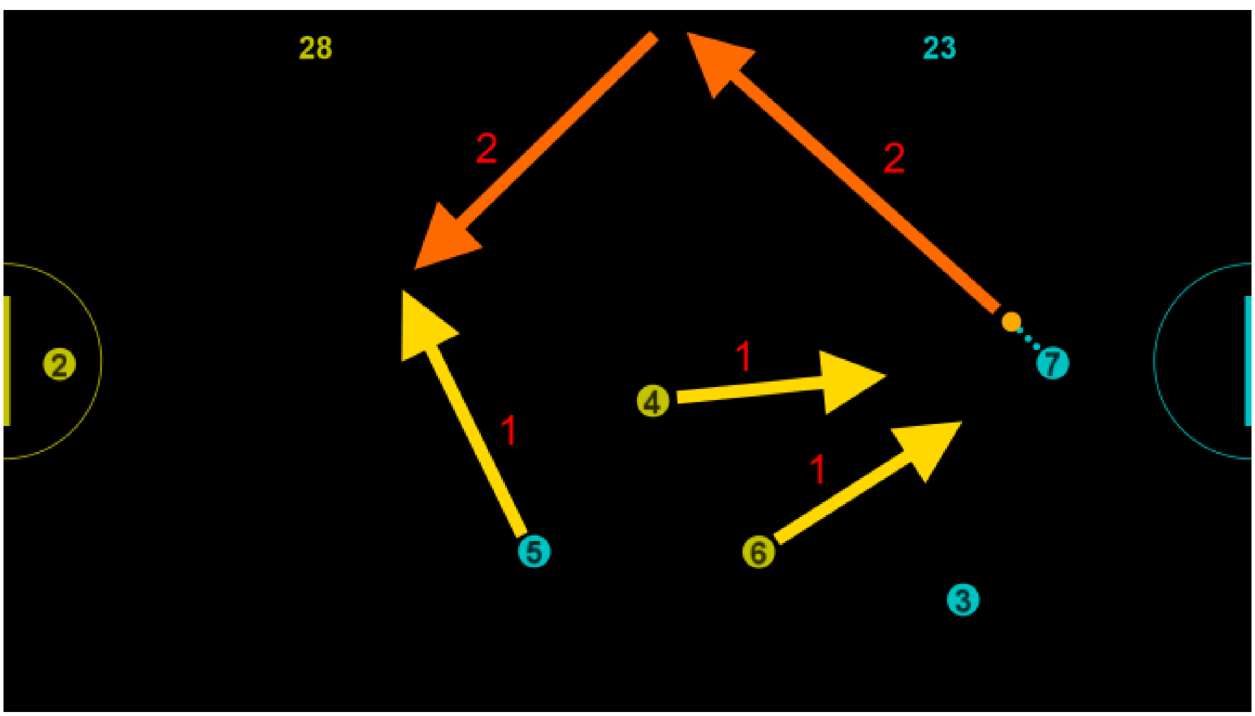

Figure 4.5: Bank pass.

The league had a one-week break in the middle of the season, and players also felt that their skills had degraded somewhat during that rest, suggesting that ‘rust’ from lack of practice occurred during the break. Player stats, however, did not change dramatically as the league continued – for example, there were similar numbers of Goals, Assists, and Shots in the first half of the league (38, 12, 196) as in the second half (30, 9, 173). Discussions with players suggests that the lack of change to the stats is a result of the global increase in skill across most of the players – that is, players became better at defense as well as offense, and so individual stats did not improve even though the overall level of play was higher.

4.4.2 Individual Skill Differences Arising from Physicality

The physicality of the Jelly Polo controls led to a wider range of skill levels in certain aspects of the game – particularly movement speed. It was very clear from observing games and from interviews that different Jelly Polo players had different top speeds. In the interviews, we asked who the fastest player in the league was. Three players received all of the votes (P5: 5 votes; P8: 4 votes; P11: 1 vote), showing that a small set of players had particularly good speed with the impulse-based controller. In the interviews and during the games, people also talked about speed differential in terms of their own abilities: for example, one person stated that for the faster players “even if I could keep up with some people, I still couldn’t catch them;” another stated that “this feels like the opposite problem I have with soccer. I can kind of shoot OK [in Jelly Polo], but I can’t run fast enough.” After being caught on several plays, P3 said: “I can’t move as fast as them!”

Figure 4.6 shows a situation where a player on a breakaway is caught by a faster opponent. Jelly 3 has an open path to the net, and is as fast as Jelly 4, but is much slower than Jelly 2. Even though he starts far behind, Jelly 2 catches up to Jelly 3 and breaks up the chance. This happened frequently in games – one participant noted “there were plenty of times where it would have been a breakaway if someone didn't charge back and cut you off.”

Player speed also became a part of team strategy – teams had to adjust to accommodate particular players’ abilities. For example, one player discussed having to defend against the speedy P5: "[he] is really fast, so it makes it hard because you can't catch up to him." P5's team sometimes made use of his speed by positioning him in the middle of the field where he could get breakaways. This forced other teams to change their strategy: one player said, "[we] had to keep one guy back to play defense on the cherry picker."

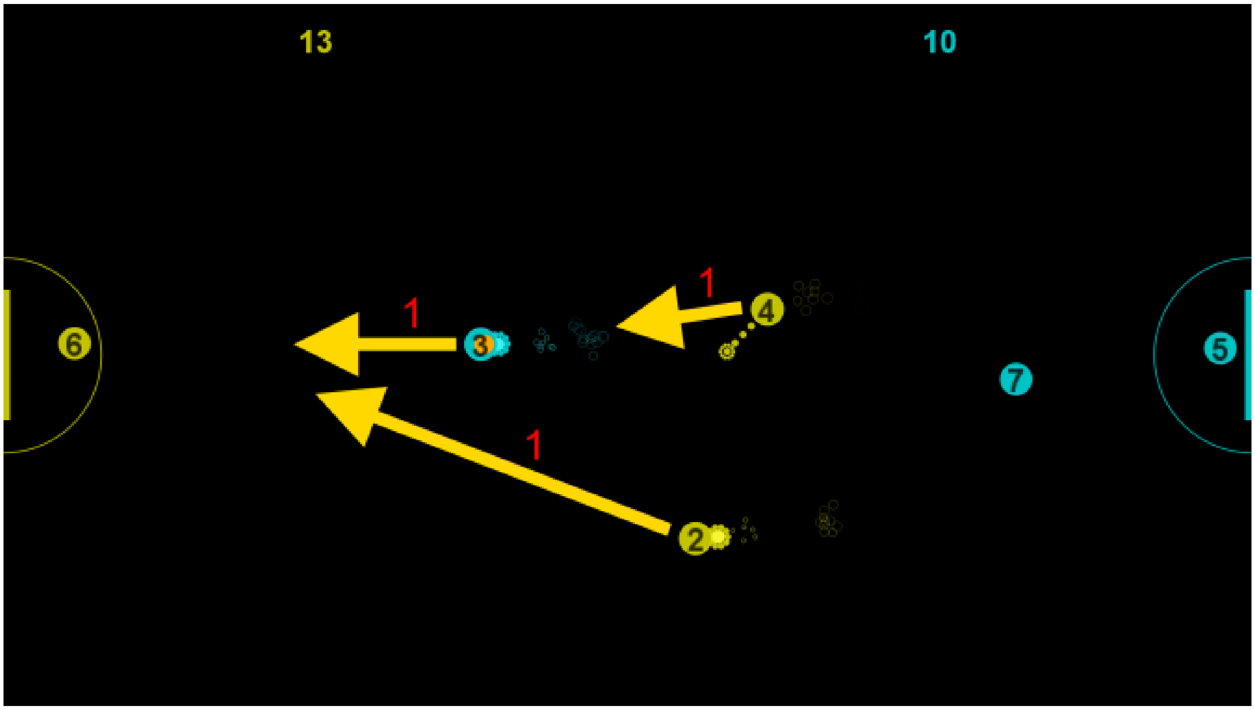

Figure 4.6: Catching a player on a breakaway

To check people's actual speeds with impulse-based control (but outside of a game situation) we carried out an informal race in which players moved as fast as they could across the playing field and back again (using impulse-based control). These races confirmed the wide range of speeds – the fastest player finished in 6.5 seconds, and the slowest in 11.4 seconds, with eight other players distributed between (see Figure 4.7).

We also looked for individual variance in the player stats, and there was clear evidence of differences in this data. For example, the stats showed large differences in Goals, Shots, Saves, and Steals (see Figure 4.8); this suggests that some players chose particular roles (e.g., playing in net and making lots of saves, but with few goals).

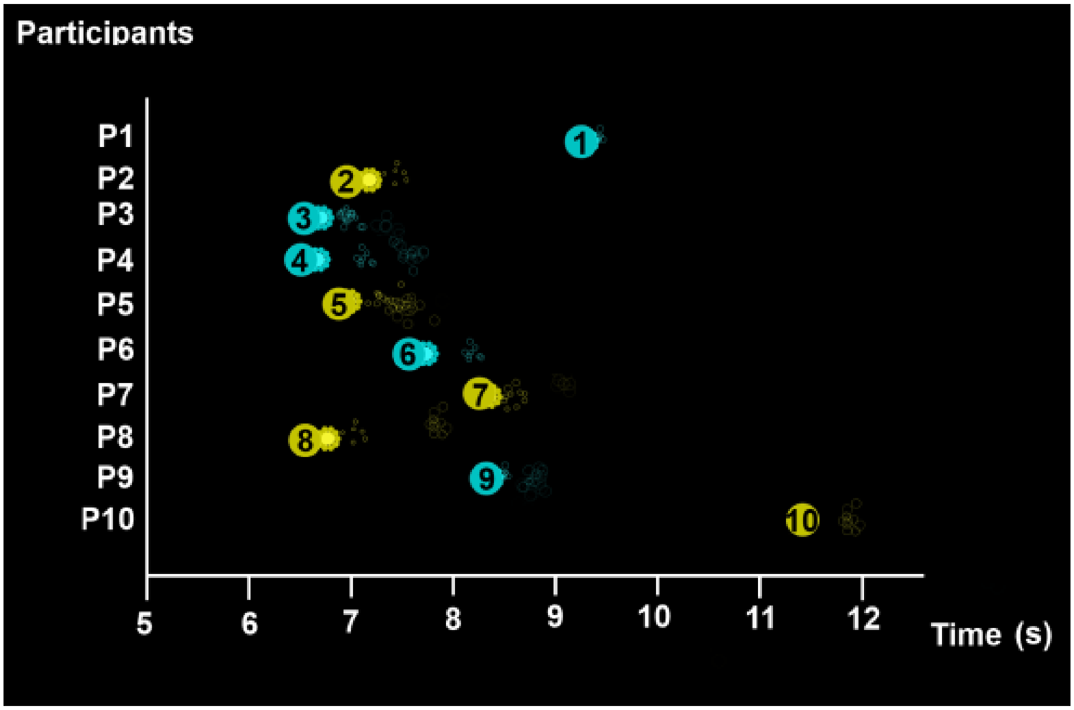

Figure 4.7: Jelly Polo race results.

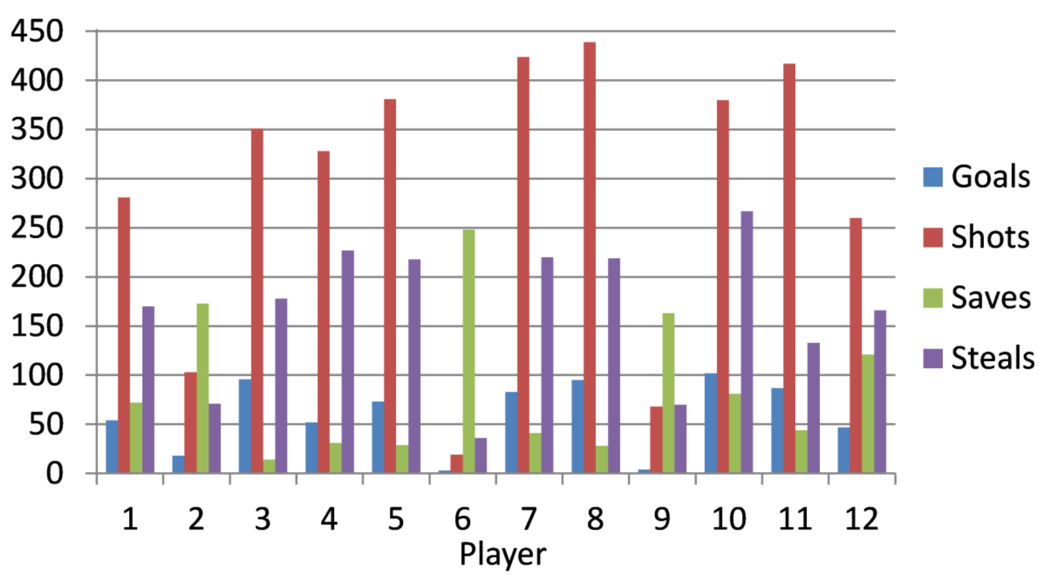

Figure 4.8: Individual player stats.

4.4.3 Changes during Games Arising from Physicality

The largest difference that was observed between traditional games and Jelly Polo was in the way that the physical controls (i.e., impulse movement) led to changes in people's movement abilities over the course of a game. The main issue was fatigue – people got tired, particularly over the short-term. The thumb-based control action required effort, and people could not perform at their maximum speed throughout the whole game. Players were able to 'sprint' with a burst of speed, but then would be unable to move as quickly until they had rested.

The effect of fatigue was clearly evident from game comments and interviews, and had a dramatic effect on both individual and team play. On an individual level, it was clear that people got tired, and that they had to adjust their play based on their fatigue level: one person stated "I got tired a bit if I sprinted back and forth, but I would usually recover before the game ended;" and P1 said "if it didn't have that [thumb-based movement] I would play offence and defense all the time; but I wouldn't go as far forward because I knew I had to go back on defense." Several people also talked about their thumbs getting sore during the game, and one player (P5) even worked so hard that he had his hand cramp up during a game: he yelled out "Cramp!" to tell his teammates that he would be out of the game for a few moments while he massaged his hand.

Several players changed their individual strategy to conserve energy. P1's comment above is one example; two other people stated that they played more in the middle of the field (e.g., "I tried to stay near the middle so I wouldn't have to run so far back and forth;" "I cherry-picked because it would give me time to rest so I could perform when I had to"), and another stated that in general "I tried to minimize movements" to maintain energy for short sprints.

Fatigue also played a major role in the way teams organized themselves. In most cases, the team's forwards had to work harder as they raced toward the other team's net or a loose ball, and so this role was generally much more tiring than playing defense. As a result, most of the teams adopted a strategy where they would switch players between forward and defense (or goalie) in order to give tired people a rest. As one person stated, "we switched off a lot so that made it [game fatigue] better." The switching-roles strategy was useful not only for resting, but also for taking opportunistic advantage of the other team's fatigue. As P10 stated, "if you had a chance to rest, then you could burst out and be faster than everyone. It was like you had the invincibility star. You could be faster than everyone else for a while." Another player found the same strategy, saying "by playing goal for a while I can kind of save up some steam, and then really go on a tear."

The idea that fatigue can be an important factor in the outcome of a game, and can play an important role in minute-to-minute strategy decisions during the game, is something that is taken for granted in real-world sports, but that is almost completely absent from sports video games. In addition, although other exertion games have had fatigue [66, 67, 69], there is little work done to use fatigue as a critical factor in the performance of the game itself. Finally, we saw evidence that the effort and physical difficulty of our movement mechanism actually made the game more enjoyable – it increased the complexity of the gameplay, it increased the degree to which teams had to coordinate their activities, and it added to the unpredictability of the game (e.g. through unexpected events like hand cramps). One player summarized this in the interviews by saying that "the interaction–like the constant flicking [i.e., impulse movement], and the effort you were putting into it, was what made it fun."

4.4.4 Expressive Communication through Physicality

'Metagaming' is discussed by Mueller [85] as part of exergames, and suggests that incorporating physicality into digital games can provide opportunities for additional bodily expression and communication. We found many instances of expression through physicality in Jelly Polo. Players would use their character's arm for a number of different expressions – spinning their arm around, 'high fiving' each other, or poking other players.

Players could also bounce off another player if they ran into each other. This body checking mechanism was rarely used during gameplay to gain an advantage over the other team, but was often used to taunt other players. This happened especially at half time or before the game began. Players also chased one another around the screen at these times – either to play a game of keep-away with the ball or to run away until the other player could make contact with them, like a game of tag.

4.4.5 Follow-Up: Rate-Based Jelly Polo

We were interested in the degree to which players' enthusiasm for Jelly Polo was related to the physical movement controls, so we created a version of the game with rate-based movement. The game was the same as before (graphics, arm movement, and rules), but in this version players could simply hold the left thumbstick in any direction and their jelly would move in that direction at a constant rate. Two teams (six people) who played in the Jelly Polo league played one game with the rate-controlled version, and discussed the game over a period of about an hour.

The players' response to this version of the game was overwhelmingly negative. The first comment heard during the game was, "It's terrible when you can't catch up to someone [by moving faster]." Players also complained about not being able to fake as well because the defense could stay on you so much easier now. One participant said "this sucks."

After the much-quieter-than-usual game, players were asked what they thought about the change in movement control. Players agreed that they disliked it: for example, P1 said "I thought it was really annoying." When asked to compare this version of Jelly Polo to the original, players pointed to both the overall excitement of the original, and to the physical basis for that enjoyment: one player said "way less exciting;" another stated "you don't have to put as much effort into it," and a third said "it doesn't force you to get as involved."

This exercise suggested that without the physicality added to the game, players did not have as much fun, and team strategies would not change as much because there was no fatigue factor. Without differentiation and changes over time, the game seemed unrealistic and less competitive.

4.5 DISCUSSION

The preliminary Jelly Polo study had four main findings:

- Physical controls allowed expertise development over time, particularly for precise passing;
- Impulse-based control of movement led to clear individual differences in player abilities;
- Physical movement control also clearly led to changes in player capabilities over time, with fatigue becoming a major factor in game outcomes and game strategy;
- Physical control appeared to add to the complexity and unpredictability of Jelly Polo, leading to greater player expressiveness, enjoyment, and enthusiasm.

In the following section, we consider reasons why physical controls had these effects.

4.5.1 Explanation for Results

There are several ways that physical controls added to the play experience of Jelly Polo. First, the added complexity of the gameplay with physical controls made a major difference in the play experience. Second, the element of uncertainty that physical controls (and the resulting fatigue) added was another important improvement. Mueller identified this benefit in terms of exergames more generally:

> *Uncertainty contributes to an element of suspense and facilitates surprise in games through random or chance events, which can play an important part in what makes a game engaging. […] In conventional button-press computer games, any chance encounters need to be artificially introduced through explicitly programmed code […] In exertion games, on the other hand, uncertainty can also arise through the body. The body's response to exertion is hard to predict for player and technology alike ("how long can I keep up?"), and the variety of bodily movements can cause even simple actions to go wrong (e.g. missing a free-throw in basketball or a short putt in golf). [70], p. 2653.*

Although Mueller was discussing larger-scale exertion games, our experience is that even small-scale physicality can provide exactly this kind of uncertainty, leading to enhanced enjoyment and interest in the game.

Third, the added level of commitment that exertion required appeared to enhance the play experience for players. There were many comments heard during Jelly Polo games that would not have been out of place on a real-world sports field – this is best characterized by P10's exhortations to his teammates in the final Jelly Polo game: "DIG! DIG! DIG!" The physical requirements clearly meant something to the players, and changed the play experience from a casual encounter to a more personal contest. This element was clearly lacking from the rate-based version of Jelly Polo, and players quickly saw and understood the critical difference between these versions.

Fourth, the expressiveness of complex physical controls seemed to be an area that players greatly enjoyed. Players quickly and naturally made use of the full range of communicative capabilities of the Jelly characters. Although this kind of communication also occurs in commercial sports games, it is important to note that the physical control scheme added considerable range to what players were able to express.

4.5.2 Final Thoughts

The results of this study showed that the principles of exertion interfaces can also exist 'in the small' and in the traditional game environment, and suggest that game designers should consider exertion as a way to improve play experience in games based on physical activities. Small-scale exertion improved all three problems identified in sports video games, and made a sports game which was more competitive, based on player skill, and sport-like than traditional commercial titles. Players liked the impulse-based version of Jelly Polo as compared to the rate-based version; however, players only played one rate-based game, and only after an entire league of the impulse-based version (see Chapter 6 for a more detailed exploration of differences between these two versions of the game).

Our next step was to quantify exactly how much expertise development, differentiation, and fatigue occurs using our Jelly Polo control scheme. The study above primarily used qualitative data; Chapter 5 gathered quantitative data about the effects of impulse-based movement and precision passing.

CHAPTER 5

QUANTITATIVE STUDY COMPARING TRADITIONAL RATE-BASED CONTROLS TO SMALL-SCALE EXERTION

This chapter gathers empirical data to show expertise development and individual differentiation in terms of gains in speed and passing accuracy. We also attempted to empirically show fatigue. For this study, we did not have participants play a game using small-scale exertion; instead, we created three skill-based tasks for participants to complete using the controls described for Jelly Polo. The three tasks were a running race to test maximum and average speed, an obstacle course to test maneuverability and average speed, and a passing drill to test accuracy and precision of throwing. We also included traditional rate-based controls, along with our implementation of impulse-based controls, to get a comparison baseline. This study empirically shows that expertise development and individual differentiation are present in impulse-based movement and precision throwing, and fatigue was displayed within tasks but not between tasks.

5.1 TASK DESCRIPTIONS

For this study, we created three tasks by modifying our small-scale exertion game Jelly Polo. The first two tasks, the running race and obstacle course, were completed using both impulse and rate-based controls. The final task, the passing drill, used precision throwing from Jelly Polo and was not compared to any other control schemes since traditional controls (i.e., semi-automatic passing) would lead to perfect scores in the task. Below are detailed descriptions of each task.

5.1.1 Speed Test: Running Race

In this task, participants used their controller to move an on-screen character across the game screen and back again, as quickly as possible (see Figure 5.1). Participants started at the left side of the screen, and after a 5-second countdown, “ran” to touch the right edge of the screen, then turned around and returned to the finish line at the left side. The right wall turned green once they had touched the wall successfully. The impulse-based and rate-based versions of this task were exactly the same other than the control scheme used.

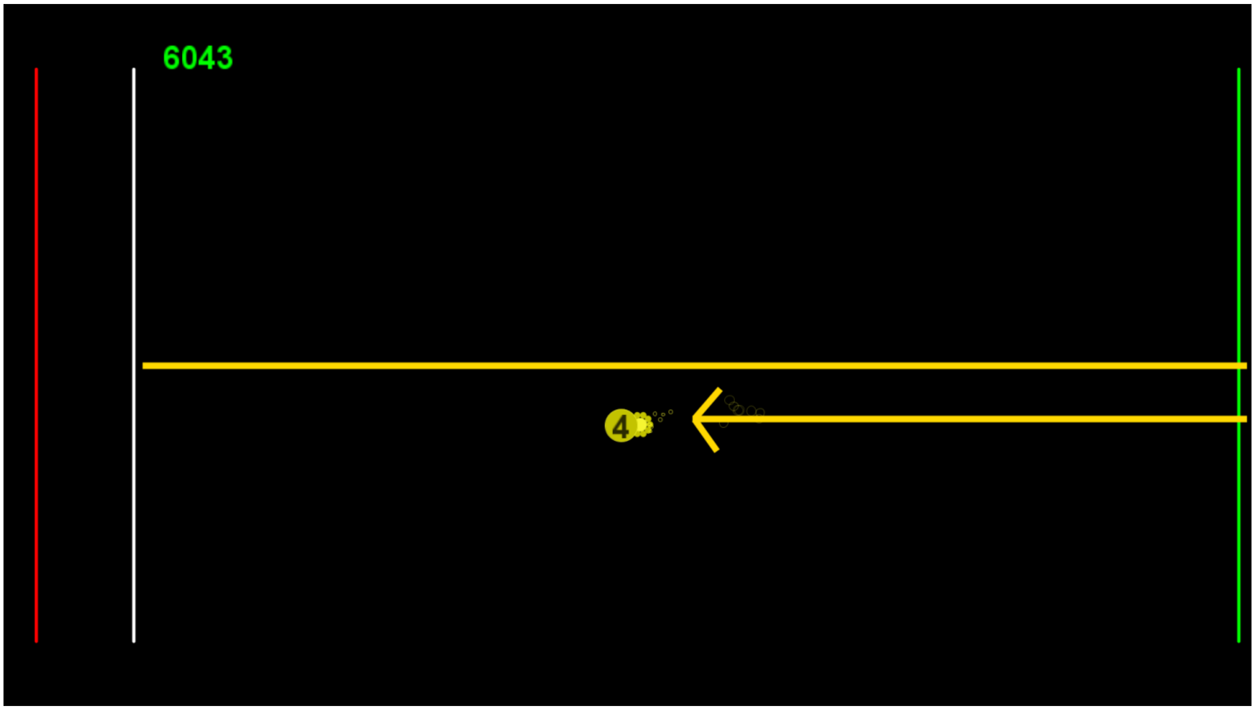

Figure 5.1: Race in progress (timer at top left; arrow shows path of motion but was not shown in the trials).

In order to give the participants a sense of how well they were doing (i.e., Schmidt and Lee's strategy of *knowledge of results* from section 4.2 [86]), and to give them a goal to beat for the next race, the total time (in milliseconds) was displayed during and after the race.

5.1.2 Maneuverability Test: Obstacle Course

In this task, participants moved their character in a particular path around a series of obstacles, as quickly as possible. Participants began in the "start" circle (Figure 5.2, left), and after a 5-second countdown, began moving around the obstacles in the path shown in Figure 5.2. They finished by returning to the start circle. Once each arrow was passed correctly, they would turn from white to green. If the participant hit an obstacle they would bounce off; this would cause them to lose time and could take them out of their movement rhythm. In the study, participants ran multiple laps of the obstacle course in a row. Each lap time was displayed during the next lap's countdown, again to provide a goal and spur performance. The impulse-based and rate-based versions of this task were exactly the same other than the control scheme used.

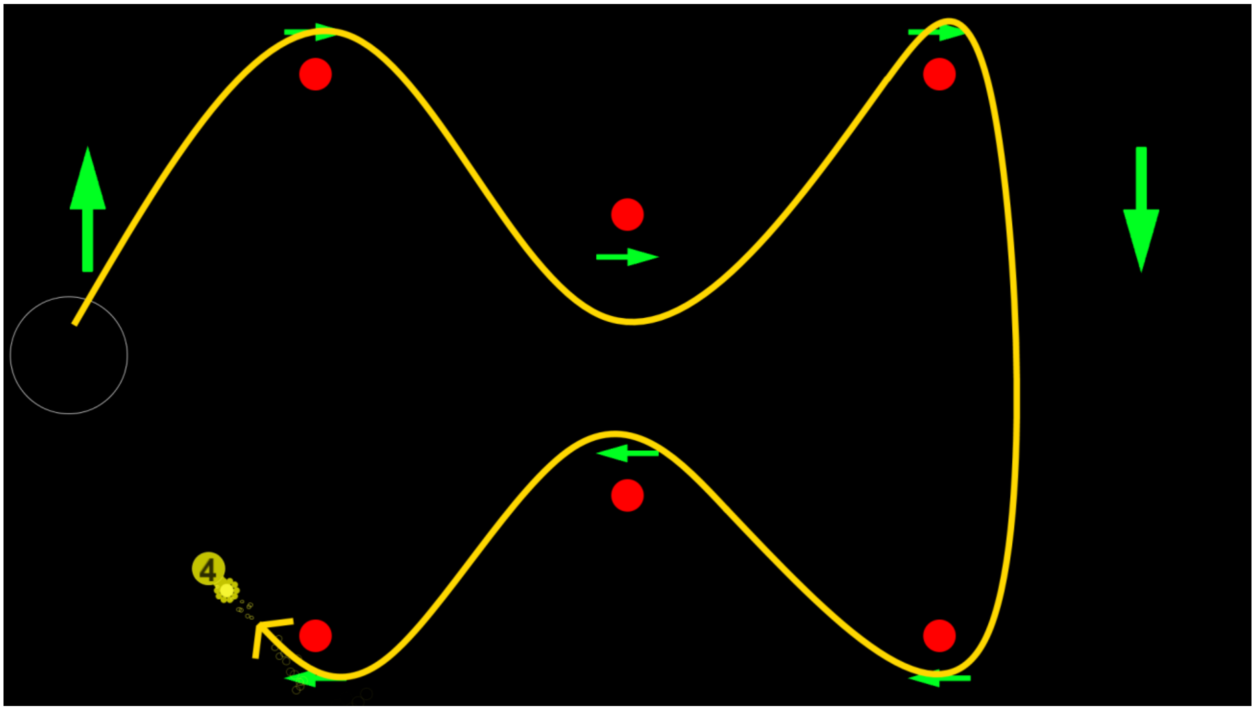

Figure 5.2: Obstacle course in progress (curved arrow shows path and was not shown in the trials).

5.1.3 Accuracy Test: Passing Drill

In this task, participants controlled their character to throw a ball at a series of moving targets. Figure 5.3 shows a diagram of the task setup and all targets. The participant was put in the middle of the screen without the ability to move. A series of round targets appeared, one at a time, as shown in Figure 5.3; the targets moved back and forth in a predictable linear pattern. There were three difficulty levels in the targets: easy (close (200px) + slow), medium (middle distance (300px) and medium speed), and difficult (far (400px) + fast) and four directions: right, up, left, down. There were 12 targets in all, three difficulty levels at each of the four directions.

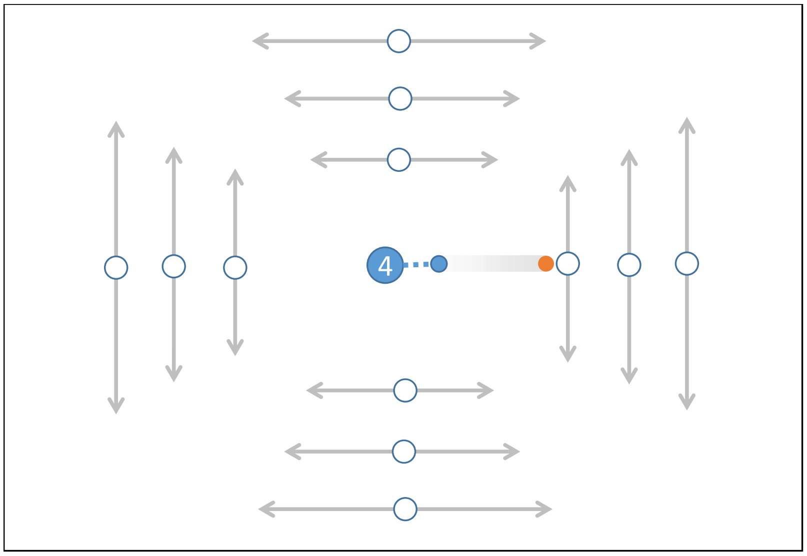

Figure 5.3: Diagram of passing task, showing all target locations and movement patterns.

The participant's goal was to throw the ball as close to the target as they could. Participants were clearly told that speed did not matter in the passing section of the study; we were only asking them to be as accurate as possible. Once the participant attempted the pass, we kept track of the shortest distance between the ball and the target throughout the entire motion of the ball. If the ball made contact with the target, the target would turn from red to green. This was to give participants some feedback and a sense of accomplishment when they got close to the target.

Once the ball either hit a wall or stopped its motion, it was moved back to the participant for the next throw. Participants were given five attempts at each target one by one (e.g., five attempts at right+easy then move to the next target). Once the five attempts were taken, the next counter-clockwise target appeared; in addition, all targets of one difficulty level were done before moving to the next level.

5.2 STUDY METHODS

5.2.1 Participants

Twelve participants were recruited from the University of Saskatchewan (7 male, 5 female; mean age 25.2 years). Nine of the participants played video games regularly (>3-7 hours per week), and seven participants were familiar with sports video games (>1 hour per week). Participants rated their prior experience with a video game controller on a 7-point scale (1 = I've never used them; 7 = I'm an expert). Participants also rated how often they used the thumbsticks when playing games with a controller on a 7-point scale (1 = Never; 7 = Always). Table 5.1 shows the frequencies of responses to these two questions. Participants were given $15 for their participation in the study.

Table 5.1: Frequency table for demographic questionnaire.

Question	1	2	3	4	5	6	7
Experience with a video game controller	0	0	2	6	2	1	1
How often participant uses thumbsticks	1	0	2	2	1	2	4

5.2.2 Apparatus

The study used custom software built in Processing [77] using the Procontroll library [78] (see section 4.1) for the controllers and ran on a Core i3 Windows PC using a 23.6 inch Asus monitor. Each participant used the same Logitech Dual Action Gamepad for the controller (see Figure 4.3). The controller was connected to the PC's USB port. A Microsoft keyboard was used to transition from one task to the next. Participants sat in front of the monitor.

5.2.3 Procedure

Our goals were to determine the presence and magnitude of individual variability, skill development over time, fatigue, and differences between the two control schemes. To reach these goals, we had participants run through a certain number of tasks over three separate sessions. Sessions had gaps of two days and seven days between them. As an example, if the first session was a Monday, the second session would be Wednesday, and the third session would be the following Wednesday. In each session participants started with impulse-based controls and ran one race, then 10 laps of the obstacle course in a row, then one more race. Between tasks, each task was explained to make sure participants knew what their goals were. Next, participants ran through the same tasks, but with rate-based controls. After the rate-based tasks were finished, the last task was the passing drill. All three sessions were identical and participants were asked to try and improve over time at all tasks. In total, each participant ran through the race task 12 times (6 in impulse, 6 in rate), completed 60 laps of the obstacle course (30 in impulse, 30 in rate), and performed the passing drill 3 times (180 passes total).

5.2.4 Measures

The quantitative data was collected by the system during each task. During the running race, a timestamp with on-screen character position and speed data was logged by the system; during the obstacle course, a timestamp with on-screen character position, speed, and number of obstacles hit were logged by the system; during the passing drill, the ball's minimum distance to the target on each pass attempt and number of targets hit were logged by the system.

For the running race, to look for differences in individual variability across control types, we recoded our dependent measures (average speed and max speed) as the percent difference between the participant's score and the overall mean (we call this measure *variability*). We analyzed variability across control type with a one-way RM-ANOVA with a single within-subjects factor, Control Type (impulse or rate). To look for expertise development, fatigue effects, and differences across control types, we used a 2x2x3 RM-ANOVA with three within-subjects factors: Control Type (impulse, rate); Race (1, 2); and Session (1-3). Dependent variables were average speed and maximum speed. We also looked for fatigue within races with two additional measures: number of speed drops during the race, and the amount of time participants were able to move at nearly their maximum speed.

For the obstacle course, we measured participant variability with the same method used for the running race. We analyzed variability across control type with a one-way RM-ANOVA with the factor Control Type (impulse, rate). To look for expertise development, fatigue effects, and differences across control types, we used a 2x10x3 RM-ANOVA with three within-subjects factors: Control Type (impulse, rate); Lap (1-10), and Session (1-3). Dependent variables were average speed and number of collisions.

For the passing drill, both control types used the same passing controls, and fatigue was not a factor in the passing test, so here we analyze individual variability and expertise development. Variability is again calculated as the percent difference between a participant's accuracy and the mean accuracy; the same is calculated for precision. There is no comparison of control types, because the real-world technique used in sports games is semi-automatic, which has a near-100% success rate for passing. Expertise development is analyzed using a 4x3x3 RM-ANOVA, with three within-subjects factors: Direction (up, down, left, right); Difficulty (close+slow, medium+medium, far+fast); and Session (1-3). Dependent variables were error and targets hit.

After the impulse-based tasks, and again after the rate-based tasks, participants filled out a questionnaire consisting of 7-point Likert scale questions. Questions included levels of mental and physical demand, if participants felt they got better or could still improve at moving the character, and if they thought they were successful at the task. A full list of the questions can be found in Table 5.2. After the passing drill, a similar questionnaire was given; instead of questions relating to movement of the character, they were pertaining to the accuracy of passing (i.e., "I feel like I got more accurate at passing the ball" instead of "I feel like I got better at moving the character"). Table 5.3 contains the questions asked in the passing questionnaire.

Table 5.2: Questionnaire questions received after impulse and rate-based tasks.

Question Number	Question
1	The tasks were mentally demanding
2	The tasks were physically demanding
3	My thumb/hand/wrist got tired during the tasks
4	I feel like I got better at moving the character
5	I think I can still improve on moving the character
6	I was successful in accomplishing the tasks
7	I worked very hard to accomplish my level of performance

Table 5.3: Questionnaire questions received after the passing drill.

Question Number	Question
1	The tasks were mentally demanding
2	The tasks were physically demanding
3	My thumb/hand/wrist got tired during the tasks
4	I feel like I got more accurate at passing the ball
5	I think I can still improve on my accuracy passing the ball
6	I was successful in accomplishing the tasks
7	I worked very hard to accomplish my level of performance

At the end of the third session, each participant filled out a final questionnaire. This final questionnaire was made up, again, of 7-point Likert scale questions. There were specific questions for each control type (i.e., impulse and rate-based controls), there were questions comparing both movement control types (e.g., "Which control type was more fun?" with 1-Impulse and 7-Rate), and there were questions about passing. Table 5.4 has a list of the questions asked in the post-study questionnaire. After participants filled out this final questionnaire, there was a short informal interview about the study. This interview was audio recorded. Table 5.5 has a list of general questions used as starting points for the interview.

Table 5.4: Post-study questionnaire questions with frequency results.

Question	1	2	3	4	5	6	7
Scale for questions in this section: 1 = impulse-based; 7 = rate-based							
Which control type was more mentally demanding	2	2	2	2	2	2	0
Which control type was more physically demanding	8	4	0	0	0	0	0
Which control type was more fun	1	2	4	1	2	1	1
Which control type was more boring	0	2	0	3	3	3	1
Which control type was more frustrating	3	2	3	2	1	1	0
Which control type was more challenging	5	5	1	0	0	0	7
Which control type would you prefer to use when playing video games	0	0	1	3	2	2	4
Which control type would you prefer to use when playing sports video games	0	2	3	2	1	1	3

If you wanted to get better at a video game, which control type would best allow for this	1	3	3	0	2	2	1
Scale for questions in this section: 1 = disagree; 7 = agree							
I feel like I got FASTER overall at moving my character using the impulse based controls	0	0	2	1	3	2	4
I feel that I could still get FASTER at moving my character using impulse based controls	0	0	2	1	0	4	5
I feel like I got better overall at CONTROLLING my character using the impulse based controls	0	0	0	2	5	4	1
I feel that I could still get better at CONTROLLING my character using impulse based controls	0	0	1	0	2	2	7
In the obstacle course, I sometimes felt like my time increased (got worse) because my thumbs/hands got tired and I moved my character slower using impulse based controls	1	2	0	0	3	4	2
I feel like I got FASTER overall at moving my character using the rate based controls	1	3	0	1	5	1	1
I feel that I could still get FASTER at moving my character using rate based controls	2	3	2	1	3	1	0
I feel like I got better overall CONTROLLING my character using the rate based controls	0	0	0	1	4	4	3
I feel that I could still get better at CONTROLLING my character using rate based controls	0	1	0	2	2	4	3
In the obstacle course, I sometimes felt like my time increased (got worse) because my thumbs/hands got tired and I moved my character slower using rate based controls	7	2	1	1	1	0	0
I feel like I got more accurate overall at passing	0	0	2	1	3	3	3
I would like to play sports video games with the style of passing used in this study	0	1	0	2	5	1	3

Table 5.5: Post-study interview questions.

Question Number	Question
1	Overall what did you think of the flick movement, by itself or compared to the other movement
2	Would you rather play games using the flick movement or regular movement
3	Do you think some people would like the flick movement
4	Do you think first time players would be put off by the physical aspect of the flick movement
5	If you were to watch other players play, would you rather watch them use rate based or impulse based controls
6	Do you think people would want to play games where they can practice movement and get better
7	Do you think controls like these would work for game genres other than sports video games

5.3 RESULTS

We organize our results below by the three skills we tested (running (race), maneuvering (obstacle course), and passing). For each skill, we explored four main issues:

- *Individual variability* – were players different in their performance, and by how much;
- *Expertise development* – how did player performance change over time, and by how much;
- *Fatigue* – did performance change over an individual session, and by how much. Fatigue is analyzed only as a performance measure as we did not use any physiological measures;
- *Differences between control schemes* – are there differences between impulse-based and rate-based controls in terms of individual variability, expertise development and fatigue.

It is important to note that we did not compare values between the control schemes. This is because they are arbitrary depending on how the developers determine the speed variable in their system. We only compared differences in how the values increased or decreased.

5.3.1 Running Race

For the running race, we collected maximum speed and average speed per participant, and also calculated variability (mean percent difference from the group average, as described above). Figures 5.4-5.6 show the results for the two control schemes.

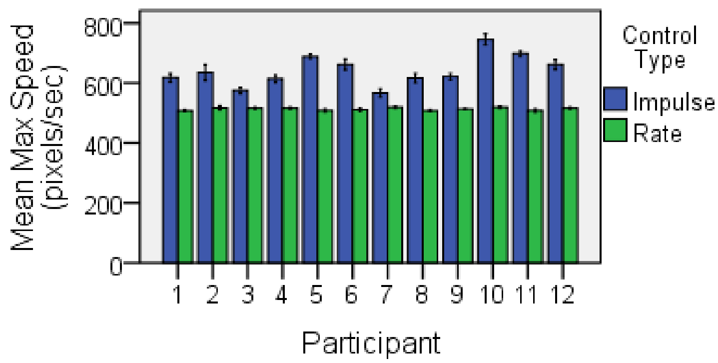

Figure 5.4: Mean max speed across all races (± s.e.), by participant.

5.3.1.1 Running – individual variability

RM-ANOVA showed a main effect of Control Type on Max Speed Variability ($F_{1,11}$=18.51, p<0.001). The variability with impulse-based control was more than 6%, and less than 1% for rate-based control.

We carried out similar analyses on average speed. RM-ANOVA showed a main effect of Control Type on Average Speed Variability ($F_{1,11}$=16.20, p=0.001). There was much higher variability in performance with impulse-based control (12%) than with rate-based (1.5%) as seen in Figure 5.5.

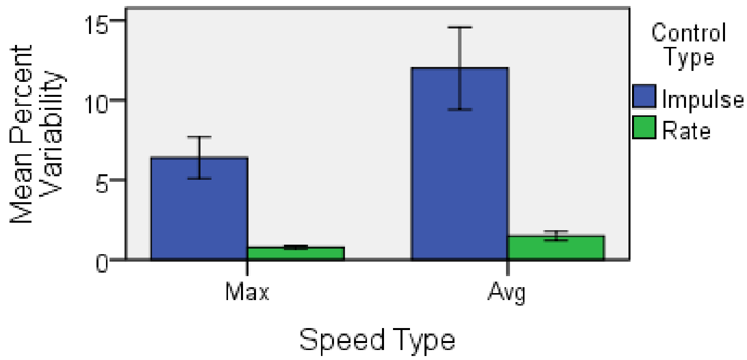

Figure 5.5: Mean percent variability in max and average speed (± s.e.).

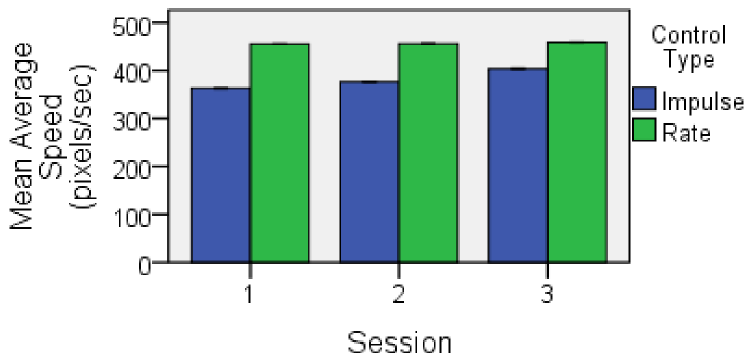

Figure 5.6: Mean average speed (± s.e.), by session and control type.

5.3.1.2 Running – expertise development

RM-ANOVA showed a main effect of Session on Average Speed ($F_{2,22}$=325.32, p<0.001). There was also an interaction between Control Type and Session ($F_{2,22}$=228.80, p<0.001); Figure 5.6 shows that the increase in speed for impulse-based control was much larger than for rate-based control (impulse: 11.3% faster by final session; rate: 0.8% faster).

For Max Speed, an RM-ANOVA showed no main effect of Session ($F_{2,22}$=1.27, p=0.28) and there was no interaction between Control Type and Session ($F_{2,22}$=1.07, p=0.35).

5.3.1.3 Running – fatigue

We looked for speed changes during a race (short-term fatigue), and changes across race (longer-term fatigue). To examine short-term fatigue, we used two performance measures: first, the number of speed drops of more than 100 pixels/sec, indicating the number of times people slowed down substantially (we used a 15-sample rolling average for this measure, to smooth the effects of the impulse-based mechanism); and second, the fraction of the total race where speed was at or above 90% of the maximum speed for the race.

Figure 5.7 shows representative data from impulse and rate-based races for one participant; these charts clearly show the higher variability in the impulse version. RM-ANOVA on both measures of short-term fatigue showed significant differences between impulse and rate-based movement: for number of speed drops, $F_{1,11}$=110.01, $p<0.001$ (mean of 5.4 drops for impulse vs. 0.24 for rate); for time near maximum speed, $F_{1,11}$=2298, $p<0.0001$ (13.9% for impulse, 95.5% for rate) Figure 5.8 shows these results.

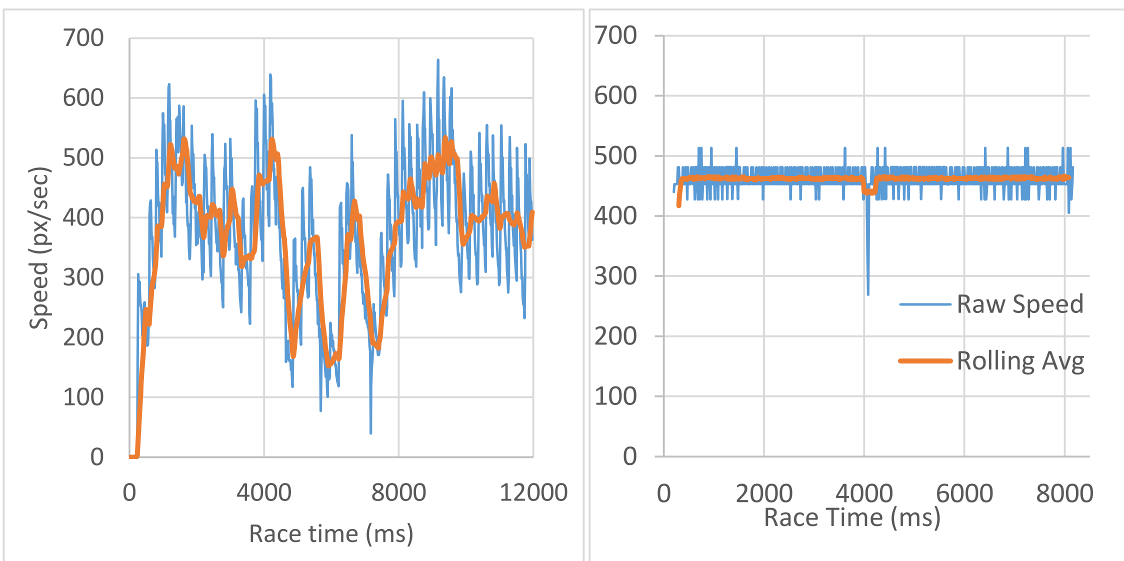

Figure 5.7: Example data for impulse (left) and rate races.

These results fall in line with the expectations of prior physiological research on muscle fatigue. The muscles of the thumb and hand (used for repeated flicking motions in impulse control) contain fast-twitch fibres that are susceptible to short-term fatigue, but can recover quickly [3]. This suggests that people cannot continuously maintain their maximum movement frequency, but can increase speed again after a short recovery period of slower movement or rest – which mirrors the bursty speed profiles seen in the data.

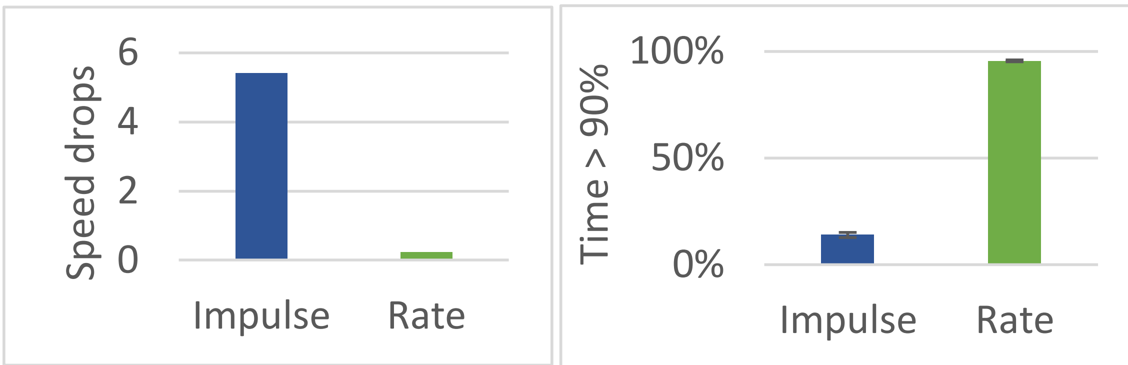

Figure 5.8: Mean speed drops per race (left) and mean time at or above 90% of maximum speed (right), by control type.

We also investigated longer-term fatigue by looking for declining average or maximum speeds in the second race of each session. However, there were no significant decreases. For max speed, there was no main effect of Race Number ($F_{1,11}$=2.74, p=0.099) and no interaction between Control Type and Race Number ($F_{1,11}$=1.99, p=0.159). For average speed, there was a main effect of Race Number ($F_{1,11}$=223.45, p<0.001) and an interaction between Control Type and Race Number ($F_{1,11}$=55.39, p<0.001) – but average speed significantly *increased* for both control types. These results suggest that practice effects overshadowed fatigue. However, subjective responses indicated that players felt the effects of fatigue (discussed below).

5.3.2 Obstacle Course

5.3.2.1 Maneuvering – individual variability

RM-ANOVA showed that the effect of Control Type on Average Speed Variability per participant was significant ($F_{1,11}$=29.95, p<0.001). Variability with impulse control was more than 8% on average, and 1% for rate-based. RM-ANOVA also showed a main effect of Control

Type on Collisions ($F_{1,11}$=5.22, p=0.032). Overall, there were more collisions with impulse-based control than with rate-based control (possibly due to the underlying higher difficulty of this method). Figure 5.8 uses absolute variability instead of percent because there is no difference between control types in the number and placement of obstacles. Therefore we took the absolute difference from the mean to find variability.

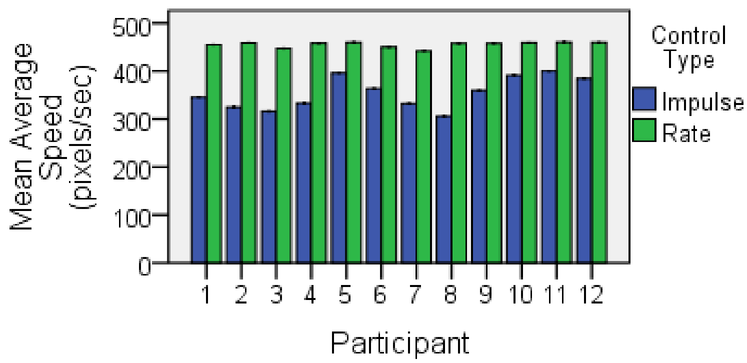

Figure 5.9: Mean average speed (± s.e.), obstacle course.

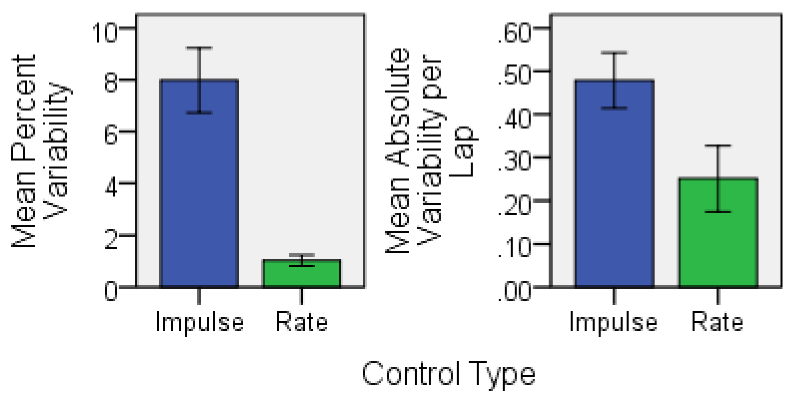

Figure 5.10: Variability in speed (left) and collisions (right) (± s.e.).

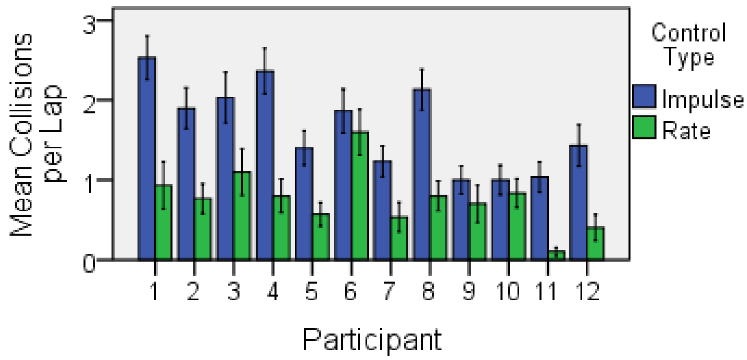

Figure 5.11: Mean collisions per lap (± s.e.).

5.3.2.2 Maneuvering – expertise development

RM-ANOVA showed a significant effect of Session on Average Speed ($F_{2,22}$=3012.35, p<0.001). There was also an interaction between Control Type and Session ($F_{2,22}$=1774.99, p<0.001); Figure 5.10 indicates that the increase in speed for impulse control was much larger than for rate (impulse: 13.3% faster by the final session; rate: 1.2% faster).

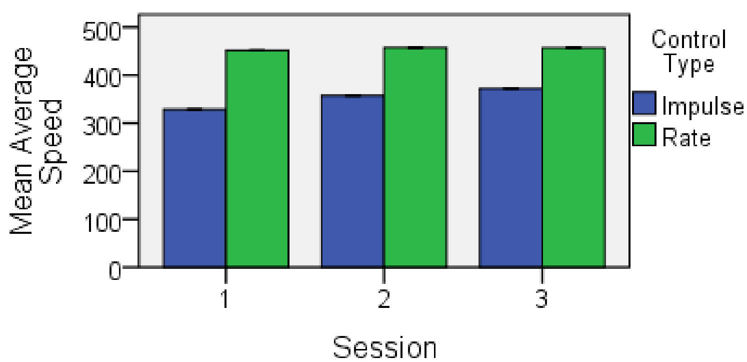

Figure 5.12: Mean average speed (± s.e.), by session and control type.

Number of collisions indicates the amount of error in the obstacle course. RM-ANOVA showed no significant effect of Session on Collisions ($F_{2,22}$=2.53, p=0.08) and there was no interaction between Control Type and Session ($F_{2,22}$=1.78, p=0.170). Figure 5.11 shows the difference between Control Type on Collisions.

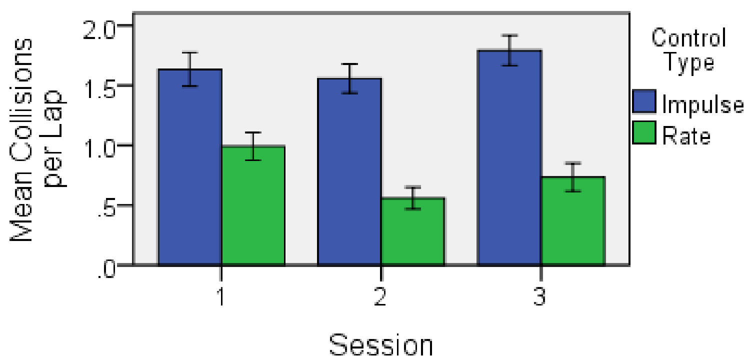

Figure 5.13: Mean collisions per lap (± s.e.), by session.

5.3.2.3 Maneuvering – fatigue

We used the same measures for short-term fatigue as described above (i.e., number of speed drops, and fraction of time spent above 90% of max). In the obstacle course, there are other factors that contribute to these measures (i.e., needing to slow down to go around obstacles) – but because the courses were equal for the two control conditions, the measures are an accurate reflection of the difference. As in the running race, there were significant differences for both measures. Impulse control had a mean of 13.2 speed drops, and rate control had a mean of 0.26 ($F_{1,11}$=436.4, p<0.0001). Percent of time near maximum speed was 5.6% for impulse, and 97.0% for rate ($F_{1,11}$=39045, p<0.0001).

To test for long-term effects of fatigue, we looked for declining average speed and increased collisions through the laps of the obstacle course. We found significant differences for average speeds with both control schemes, but in opposite directions: there was a significant increase for impulse control (21.5 pixels/sec faster by the final lap; $F_{9,99}$=82.33, p<0.001), and a significant decrease for rate control (7.69 pixels/sec slower by the final lap; $F_{9,99}$=81.13, p<0.001). It is suggested below that boredom for rate-based and practice effects for impulse-based might be a factor in this.

For number of collisions, we found no significant differences across the ten laps of the course (impulse: $F_{9,99}$=1.21, p=0.283; rate: $F_{9,99}$=0.63, p=0.769).

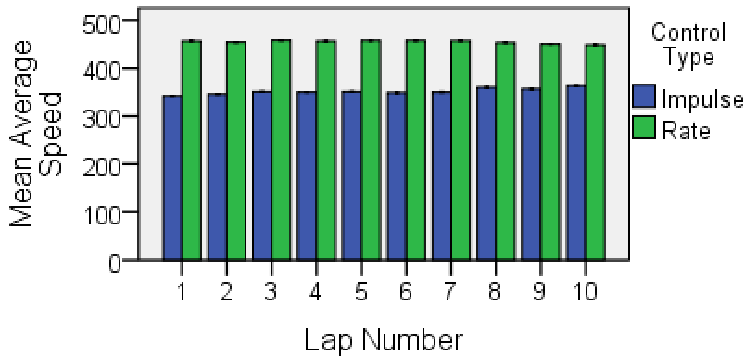

Figure 5.14: Mean average speed (± s.e.), by lap number.

5.3.3 Passing Drill

We gathered data about both *error* (the minimum distance to the target for each throw), and *accuracy* (the number of targets successfully hit with the ball). Note that there was no difference in the control schemes for the passing task, because traditional (i.e., semi-automatic) methods would lead to nearly 100% accuracy and nearly 0% error.

5.3.3.1 Passing – individual variability

An RM-ANOVA showed a main effect of Participant on both Error ($F_{2,22}$=4.909, p<0.001) and Accuracy ($F_{2,22}$=2.696, p=0.020). Figure 5.13 shows the mean of all participants' difference from the average minimum distance and the average percentage of targets hit. In a semi-automatic throwing scheme, the error would be near to zero, and the accuracy would be near to 100%.

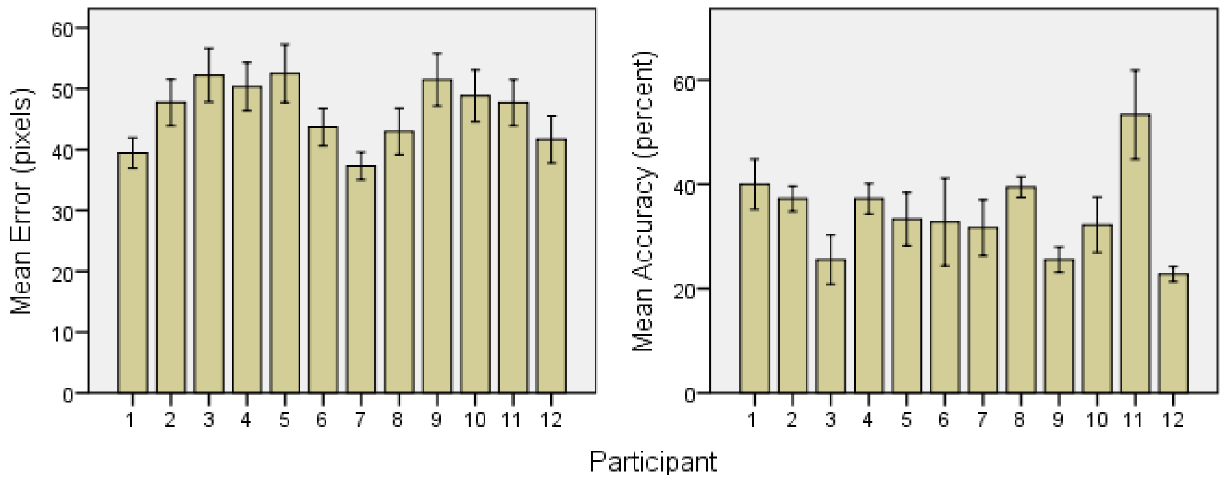

Figure 5.15: Mean error (left) and accuracy (± s.e.), by participant.

An RM-ANOVA showed a main effect of Difficulty on Error ($F_{2,22}$=33.32, p<0.001) but no main effect of Direction on Error ($F_{2,22}$=0.98, p<0.402). There was no interaction between Direction and Difficulty on Error ($F_{2,22}$=0.41, p<0.872).

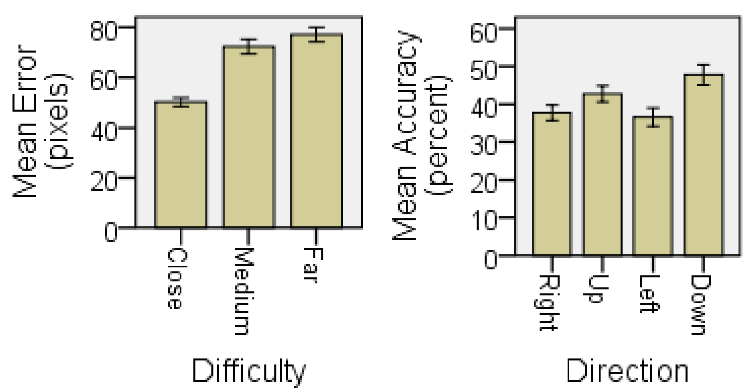

Figure 5.16: Mean error by difficulty (left) and mean accuracy by direction (right) (± s.e.).

5.3.3.2 Passing – expertise development

RM-ANOVA showed a significant effect of Session on both Error ($F_{2,22}$=14.66, p<0.001) and Accuracy ($F_{2,22}$=4.82, p=0.015).

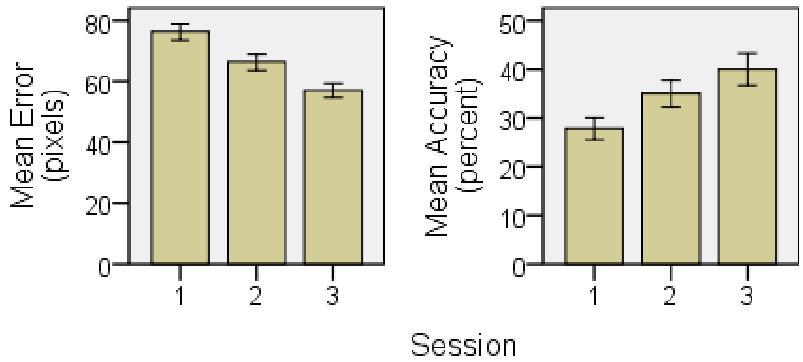

Figure 5.17: Mean error from target (left) and mean accuracy (right) (± s.e.), by session.

RM-ANOVA showed a main effect of Direction on Accuracy ($F_{2,22}$=5.45, p=0.001) but no main effect of Distance on Accuracy ($F_{2,22}$=0.00, p=1.000). There was also an interaction between Direction and Session ($F_{2,22}$=3.63, p=0.002). For Figure 5.16, mean accuracy is shown per group of five passes. Each participant, every session, had five pass attempts at each target before the target switched positions (see section 5.1.3). This meant participants had three sets of five pass attempts for each direction.

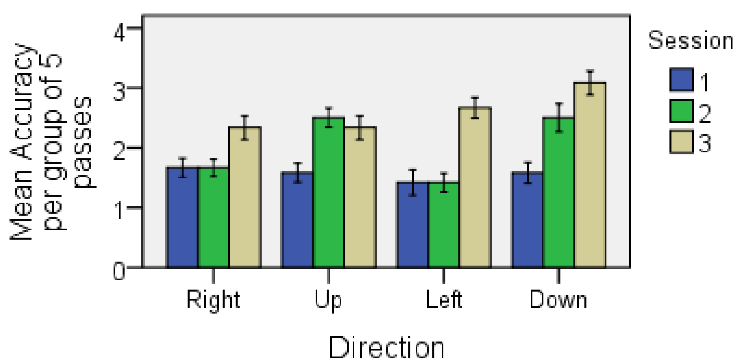

Figure 5.18: Mean accuracy (± s.e.), by direction and session.

5.3.4 Subjective Results

Participants filled out Likert-scale questionnaires after each control type for each session and one after the entire study was complete (see section 5.2.4). Wilcoxon Signed Rank Tests showed that impulse-based was significantly higher than rate-based for physical fatigue ratings (Z=-5.454, p<0.001), whether they worked harder during the tasks (Z=-7.139, p<0.001), and if they felt they could still get faster if they kept practicing (Z=-3.856, p<0.001). Figures 5.17-5.19 show these.

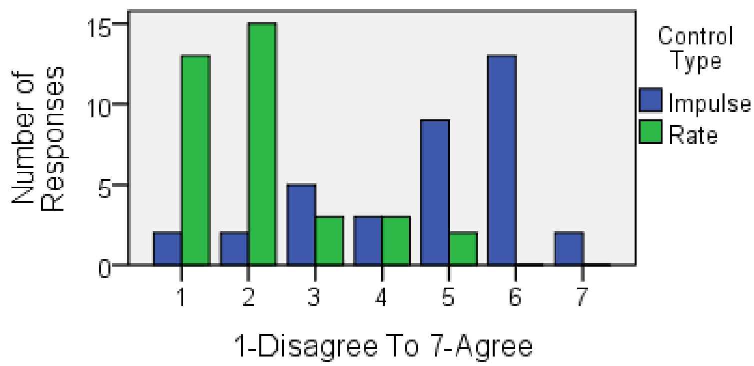

Figure 5.19: Responses to "the task was physically demanding."

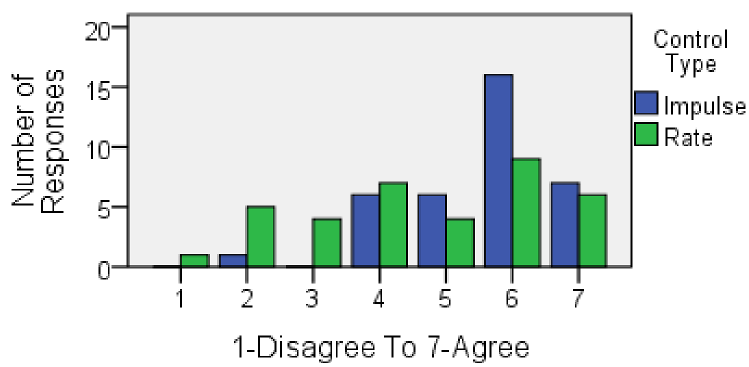

Figure 5.20: Responses to "I worked very hard to accomplish my level of performance."

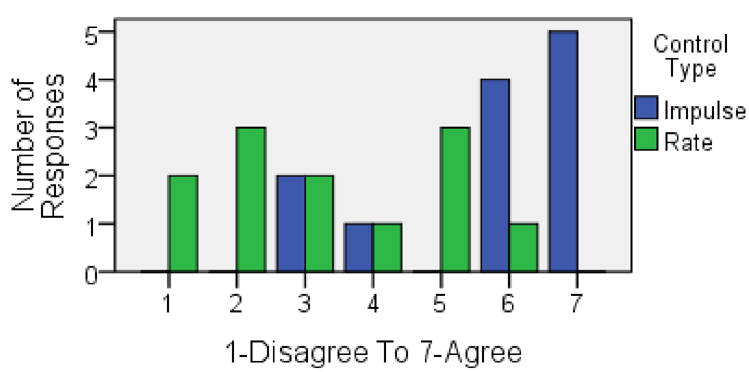

Figure 5.21: Responses to "I feel that I could still get FASTER at moving my character."

We also had subjective ratings for which control type was more boring and frustrating (see Figure 5.20: x-axis shows by how much the rating is for each control type. A rating of 1 means fully impulse, a rating of 7 is fully rate, and a rating of 4 means no difference). Rate-based controls were found to be more boring, which could explain why average speed of the obstacle course dropped across lap number, and much less frustrating than impulse-based controls.

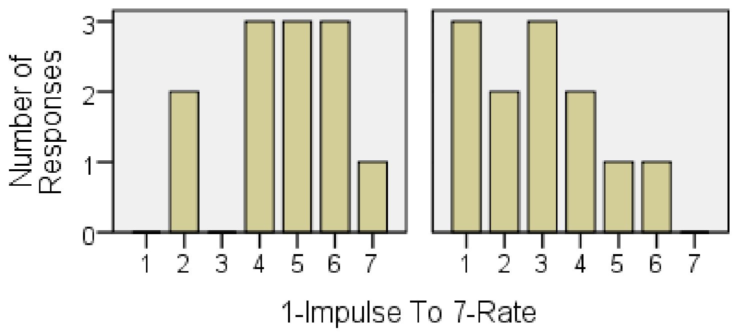

Figure 5.22: Responses to how much which control type was more boring (left) and more frustrating (right).

5.4 DISCUSSION

The second Jelly Polo study provided the following main findings:

- Individual variability in movement speed was much higher with impulse-based controls than with rate-based controls. Where rate-based controls varied only by about 1% across participants, impulse-based controls varied by about 10%.

- Skill development in movement speed was also much greater with impulse-based controls – people improved by more than 10%, whereas with rate-based controls they improved by 1-2%.

- There was substantial skill development in passing (error decreased by 23%; accuracy increased by 44%).

- There were substantial fatigue effects within races for impulse controls (significantly more speed drops, and significantly less time spent near maximum speed), whereas rate controls showed essentially no effects of fatigue. We did not see longer-term effects of fatigue (between races).

In the following sections we interpret these results and discuss their importance for informing the design of future games based on the idea of small-scale exertion.

5.4.1 Explanation for Results

In our previous study, we mostly gathered qualitative results. For this study, we collected quantitative data on the three benefits of using small-scale exertion: expertise development, differentiation, and fatigue. Although most of our results were expected, we now have empirical evidence about how small-scale exertion affects players.

5.4.1.1 Movement variability

The goals of small-scale exertion interfaces are to allow for higher individual variability and to enable greater skill development over time. This study showed that these goals were met for most of the measures. The main reason why impulse-based control had these characteristics is that it provides a higher-bandwidth control scheme that depends more on player actions than on an algorithm in the game. Human physical abilities of all kinds are highly variable, and impulse-based control superimposes this variability onto the actions of the on-screen character. Similarly, because of the underlying human variability, there is more room for improvement in most players – whereas with rate-based control, everyone is already near the top of the performance curve, so there is little opportunity for change.

Although these underlying reasons were part of our expectations for the study, the amount of variability and expertise development to be expected was unknown. The ranges that we found in the study – variability of approximately 10% from the mean, and of approximately 12% for skill improvement – are interesting from a game-design perspective because the amount of variability in the basic game mechanics can help to determine the audience for the game. For example, Jelly

Polo is designed to be an accessible game for a wide audience – and this suggests that the control schemes should allow a wide range of people to play in a walk-up-and-use scenario.

Ten percent variability means that there are noticeable differences among players, but that no one person will be able to completely dominate the game. The initial variability and the opportunity for improvement are similar to the idea of "floor and ceiling" that has been proposed for user interfaces [74] – that is, the amount that people can do when they first start with a system, and the highest level of performance that they can achieve. In these terms, small-scale exertion controls are interesting because they have a lower floor (i.e., they are more difficult to begin with); in contrast, rate-based control and semi-automatic throwing schemes start all players near the performance ceiling. It is possible that the lack of variability in sports video games arose from the designers' intention to provide equality for all players – but our participants' subjective responses suggest that taking over too much of the action leads to a reduction in engagement in the game.

In addition, the amount of potential improvement for impulse control in Jelly Polo is roughly in line with the amount of individual variability – meaning that with practice, players will experience an improvement that is similar to the differences that they see between players.

Other games may have different characteristics in terms of these issues. For example, the designer of a competitive first-person shooter may want a wider range of possible expertise and a much larger amount of possible improvement, in order to keep players interested and give them more to strive for.

5.4.1.2 Fatigue and maneuverability results

We saw local effects of fatigue in both movement activities of the study (the race and the obstacle course). The movement patterns for impulse controls (i.e., speed over time) follow the expectations suggested by physiological research on muscle fatigue. The muscles of the thumb and hand contain fast-twitch fibres that are susceptible to short-term fatigue, but can recover quickly [3].

Our measure of fatigue used performance data rather than physiological data (e.g., we did not test for lactic acid levels or other physiological occurrences). However, the simple nature of the running race and our clear instructions to move as fast as possible suggest that either true fatigue was occurring or that people were adjusting their behavior in order to avoid future fatigue (e.g., slowing down to conserve energy). From a game design perspective, both of these results are valuable – people cannot continuously maintain their maximum movement frequency, but can increase speed again after a short recovery period of slower movement or rest. Nevertheless, we plan future studies that measure fatigue more directly (e.g., with a maximum voluntary force test after each race [61]).

We did not observe longer-term effects of fatigue (i.e., across laps of the obstacle course, or between races). This may be due to the shorter duration of the activities, compared to our previous study that reported substantial fatigue; longer races might likely show more global fatigue effects. In addition, increasing expertise (or better strategy) may have counteracted any long-term fatigue effects. Finally, subjective responses showed that people felt fatigued during the activities; from a game-design perspective, being able to create the perception of fatigue may be as important as the actual phenomenon.

Finally, our maneuverability results did not show differences between impulse and rate control – and in fact, collisions increased for impulse control in the third session. From our observations, we believe that this is a result of participants becoming better at movement, and then attempting to go faster around the obstacles. This may have created a speed/accuracy trade-off and led to an increase in collisions.

5.4.2 Final Thoughts

The empirical data collected from the current study provide designers with information about the size of effects that can be expected from the use of small-scale exertion. Determining the speed values of impulse or rate-based movement might be easier, or better justified, by knowing the amount of variability to be expected between players. It may also be beneficial to know how much and how fast players increase their skills in order to determine difficulty levels in different scenarios of a game. Developers should now be able to take up this idea and use our results to create certain kinds of experiences based on individual variability and skill development.

The next step was to compare these two versions of the game more explicitly to determine if players really enjoyed the impulse-based version more. If they do, then developers should clearly see the positives in a game that adds what small-scale exertion adds (i.e., expertise development, differentiation, and fatigue), as well as making the game more enjoyable. This is what the final study explored in Chapter 6 below.

CHAPTER 6

COMPARISON BETWEEN TRADITIONAL AND SMALL-SCALE EXERTION SPORTS VIDEO GAMES

In this chapter, we compare our impulse-based version (using small-scale exertion) to a rate-based version (without small-scale exertion) of Jelly Polo to compare player enjoyment and engagement. In section 4.4.5, we observed that players enjoyed the impulse-based version more than a rate-based version of Jelly Polo. This early result suggested that small-scale exertion – which increases expertise development, adds individual differentiation, and causes fatigue – also increases game enjoyment. To test this hypothesis in more detail, we refined the rate-based version of Jelly Polo and ran a study with two Jelly Polo leagues. The results of this study showed no significant difference in enjoyment between the rate-based and exertion-based controls; in terms of engagement, however, the small-scale exertion version was significantly more engaging than the rate-based version.

6.1 GAME DESCRIPTION

For this study, we made several minor changes to the original Jelly Polo game used in Chapter 4. First, the changes made to the impulse-based version will be discussed. Following this, the changes made to the rate-based version are discussed.

6.1.1 Impulse-Based Version Changes

The core mechanics of Jelly Polo were not altered (i.e., the controls, overall look, and main rules discussed in sections 4.1 and 4.2), but we made improvements to the system. First, we removed the manual calibration step (discussed in section 4.3.3) that had to be performed before every game. We discovered that the calibration issue could be automatically fixed using code. Thus, when the game started, every player had calibrated controls (i.e., no inversion of movement or arm direction).

Second, a more thorough form of logging was added to the game. Instead of performing video analysis on every game for this study, as we did in Chapter 4, a timestamp was logged with each character's body position, arm position, and speed. In addition, the ball's position and speed, as well as which character had the ball in their possession were logged. This logging method helped to determine quantitative data about the game. More is discussed on the logging in the measures and results sections (6.2.4 and 6.3) below.

Third, how faceoffs were controlled at the start of each game, and after halftime, was changed. Instead of a free-for-all for the ball when the study conductor said 'go,' characters had to touch the wall on their side of the screen until a countdown from three was complete.

These minor modifications did not change the core gameplay, but did allow for an easier time running the study as a whole.

6.1.2 Implementation of the Rate-Based Version

In Chapter 4, a simple rate-based version of Jelly Polo was described – this initial version was used to explore how Jelly Polo functioned without small-scale exertion. The most important change made was using rate-based movement, instead of impulse-based movement. This meant that if players simply held the movement stick down in a certain direction, it followed that the character would move in that direction at a constant speed. It is important to note, however, that holding the movement stick down slightly would move the character at a slower speed as compared to holding the stick down completely. Therefore, players had control over their movement speed during regular gameplay.

Another decision to be made with the rate-based version was determining the maximum speed allowed for the characters. If the characters moved too fast, the game could appear unrealistic; too slow of movement could make the game boring. The speed was chosen based on the races performed at the end of the first Jelly Polo study (see Figure 4.7). Initially, we took the average time it took participants to complete that race and fine-tuned the rate-based speed to be as close to that time as possible when performing the same race. However, we observed that this seemed too fast. This was because for the impulse-based version, players do not move at full speed the entire game. It was unrealistic to base the rate-based speed directly on an impulse-based race where players were purposefully trying to move as fast as they could for a short amount of time. Therefore, we lowered the rate-based speed slightly until it felt natural (i.e., not unrealistically fast and not too slow).

All other aspects of this rate-based version of Jelly Polo were identical to the small-scale exertion version; precision throwing, graphics of the game, and the rules were identical. The goal was to change as little as possible in the rate-based version, while still making it free of small-scale exertion.

6.2 STUDY METHODS

6.2.1 Participants

Fifteen participants were recruited from a first-year Computer Science course at the University of Saskatchewan (12 male, 3 female). Only twelve participants' data were analyzed, as discussed in section 6.3. Participation was optional; however, course credit for their Computer Science class was given to those who participated. All participants had experience playing video games with standard controllers and 58% of participants had experience playing sports video games.

6.2.2 Apparatus

The study used custom software built in Processing [77] using the Procontroll [78] (see section 4.1) library for the controllers and ran on a Core i3 Windows PC using a 23.6 inch Asus monitor. Six identical Logitech Dual Action Gamepads were used for the controllers (see Figure 4.3). The controllers were connected to the PC's USB ports. These were the same materials that were used in the study from Chapter 4. Participants sat side-by-side in front of the monitor grouped by team. A Samsung Galaxy S3 mobile phone was used to time each game using the default stopwatch.

6.2.3 Procedure

To determine the enjoyment and engagement levels of the rate-based and impulse-based versions of Jelly Polo, two Jelly Polo leagues were run. Each league played six games. One league, league A, played their first three games using the rate-based version. The last three games for league A were played using the impulse-based version. The other league, league B, was opposite to league A (i.e., impulse-based then rate-based games).

There were two teams in each league with each team being made up of three players. The study ran for six weeks. Every Thursday, two games were played (one game from each league) for a total of 12 games (six from each league). Due to the time constraints of running the study during the participants' Computer Science class period, games were 10 minutes long. This differed from having games run 20 minutes long, as in the Chapter 4 study. As stated above, league A played with rate-based controls for the first three weeks. League B was opposite to league A (i.e., started with impulse-based controls and ended with rate-based controls). This was done to counter-balance order effects [106]. Games were run as they were in Chapter 4. The two games played each week were played one-after-another, not simultaneously.

6.2.4 Measures

As stated above, for both the character and ball, we logged position and speed data during each game. This data was used to quantitatively examine the game. After each game, the participants were given a 7-point Likert scale questionnaire to determine enjoyment level, engagement level, and physical and mental tiredness. To measure enjoyment, participants were asked to rate their agreement of this statement, "regardless of the game's outcome, Jelly Polo was fun to play." The statement regarding engagement was, "Jelly Polo was engaging." These measures were compared between leagues (i.e., league A and league B) and between game versions (i.e., rate-based and impulse-based). At the end of the entire study, another questionnaire was given to each participant. This questionnaire had a number of subjective questions, including one that specifically determined which version of Jelly Polo the participants enjoyed more and by how much. The other questions included were fourteen 7-point Likert scale questions for each game version (28 in total; see Table 6.1). For example, participants had to answer how physically tiring the rate-based version was and how physically tiring the impulse-based version was. The questions for each game version were on separate pages.

Table 6.1: Post-study Likert-scale questions (the same questions were given for both rate-based and impulse-based versions).

Question Number	Question
1	Jelly Polo was fun
2	Jelly Polo was frustrating
3	I looked forward to playing Jelly Polo on game days
4	I would enjoy playing Jelly Polo outside of the lab
5	Jelly Polo was physically tiring
6	Jelly Polo was mentally tiring
7	Jelly Polo made my thumb sore
8	I played more offense than defense
9	I passed more than I shot
10	I tried to win every faceoff
11	My team had a set strategy
12	I liked playing goalie
13	Jelly Polo is a sport
14	I got better at Jelly Polo over time

6.2.5 Special Case: Participant Zero

In order to explore the effects of playing both rate-based and impulse-based versions each week, we decided to have one special participant that would play in both leagues. Therefore, this participant, Participant Zero (P0), played in almost every game in the entire study. P0 played in 9 out of the 12 games played (4 rate-based and 5 impulse-based), missing three games due to time conflicts. The most games any other participant played were six. P0 was not officially a part of any one team, but would fill in when other players were not available to participate.

6.3 RESULTS

For the data analysis, 12 participants' data were included (10 male, 2 female). For their questionnaire data to be included in our analysis, a participant must have played in at least three games total and at least one game in each version. For example, if a participant played exclusively rate-based games, their data was not included in the analysis. This was done to fairly determine the preference of one version over the other. Not including P0, participants whose data we used played an average of 4.9 games out of a possible 6. We compared our results between leagues (i.e., league A and league B) and between game versions (i.e., rate-based and impulse-based). P0's data was not included in the comparisons, but his data will be discussed below in section 6.3.3.

Pertaining to the quantitative log data, because of the variability and unpredictable nature of the game (e.g., players played different positions, did not move at top speed the entire game because of varying factors, etc.), and the fact that participants traded off because of absences, we did not keep track of which participant was which character every game. This made it difficult to track expertise development.

Individual variability was found, however. For example, the maximum speeds for impulse-based games were highly variable (12.2% difference from the mean) across players, whereas they were not in rate-based games (0.04% difference). Average speed across players was variable in both control types (impulse=12.8%; rate=10.1%); this could be attributed to ordinary gameplay (e.g., players playing goalie compared to offense). Figure 6.1 shows variability differences between the control types for maximum speed and average speed.

Fatigue can also be inferred from our data. Participants were more likely to move near their maximum speed in the rate-based version than the impulse-based version. Participants were above 90% of their maximum speed 60.2% of the time for rate-based and 0.53% for impulse-based. In comparison, the time spent below 10% of maximum speed was relatively equal – 8.57% for rate-based and 10.6% for impulse-based. These results support what was found in

Chapter 5 and allows the same conclusions to be made for real gameplay situations as they were for the structured tasks in Chapter 5.

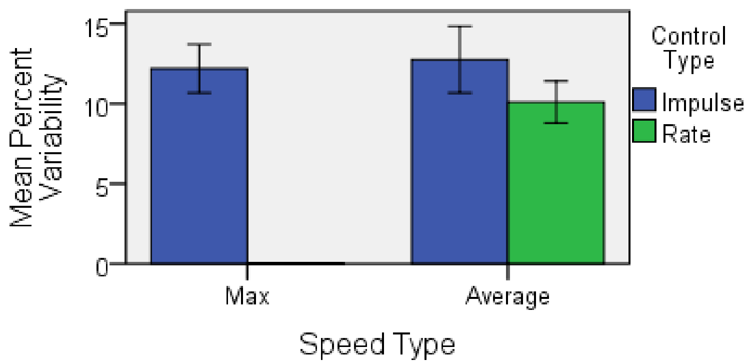

Figure 6.1: Mean percent variability in maximum and average speed (± s.e.), by control type. Rate-based maximum speed is difficult to see in the graph because it is 0.04%.

6.3.1 Comparison between Leagues

Questionnaire data was compared between league A and league B. League A and league B were similar in both their post-game and post-league questionnaires; there were no significant differences to report. This suggests that both leagues rated each game version similarly, regardless of which they played first or second.

Figures 6.2 and 6.3 show which version of Jelly Polo each league enjoyed more. The specific question asked was, "Regardless of the outcomes of the games, which version of Jelly Polo did you enjoy playing more?" Participants also rated how much more they enjoyed one version over the other using a 6-point Likert scale. If the participant rated a 1, this signified that they enjoyed the rate-based version completely over the impulse-based version. A rating of 6 meant the participant completely enjoyed the impulse-based version more than the rate-based version. For both leagues, participants gave relatively equal responses to which version they enjoyed more and by how much. Six people enjoyed the rate-based version and five people enjoyed the impulse-based version of the game (not including P0). One of the important parts of this data is that each league had a spread of ratings for each version. This demonstrates that it did not make a difference which version participants played first or last because both leagues were split in the responses to which version they enjoyed more. For example, if there was a bias in which version participants played first, then participants from league A would have all voted for rate-based and participants from league B would have all voted for impulse-based.

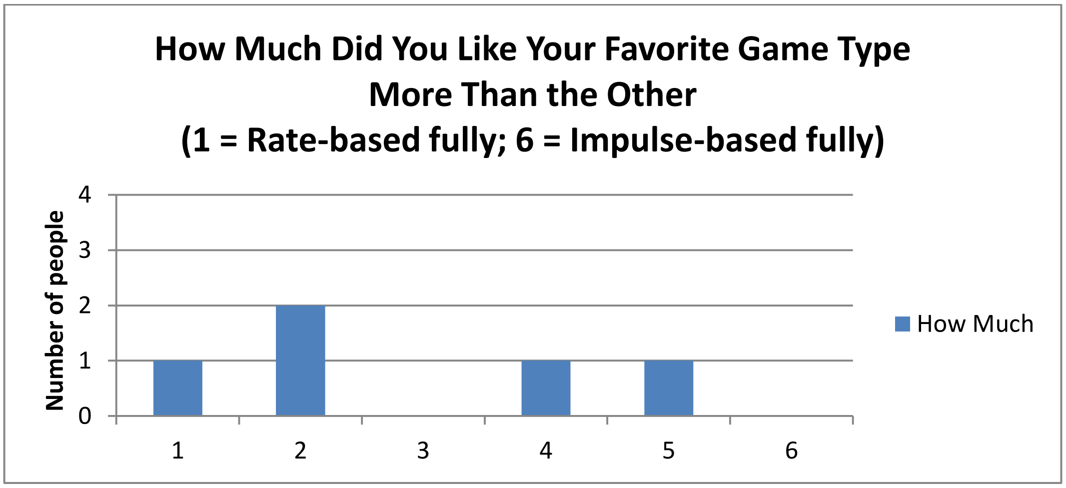

Figure 6.2: Preference of game version from league A.

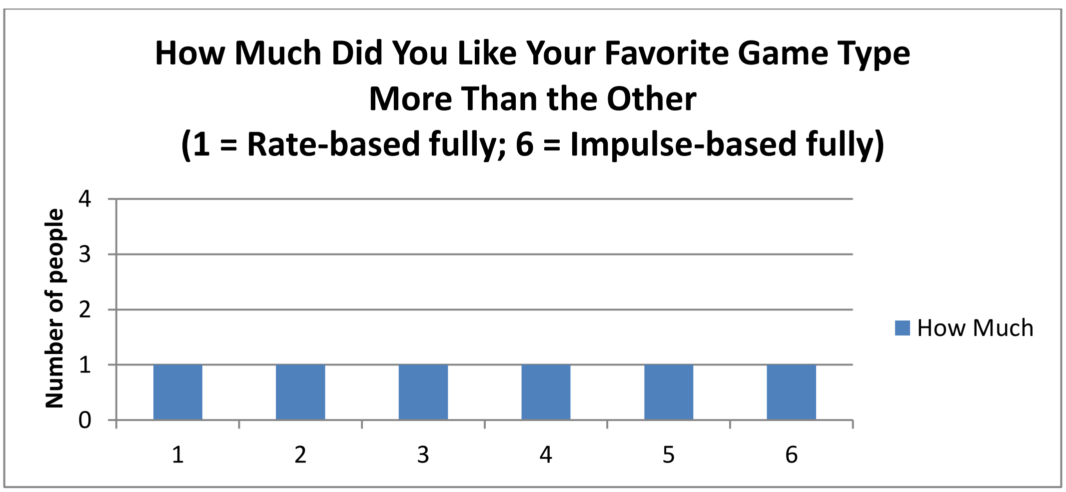

Figure 6.3: Preference of game version from league B.

6.3.2 Comparison between Game Versions

The main goals of the study were to find out if players enjoyed the rate-based version or the impulse-based version of Jelly Polo more and if one was more engaging. From the previous study discussed in section 4.4.5, it was observed that players enjoyed the impulse-based version more than the rate-based version. However, only one rate-based game was played after 22 impulse-based games in that study (18 regular season and 4 playoff games). The current study allowed the comparison between impulse-based and rate-based versions when an equal amount of games in each version were played.

Enjoyment and engagement scores collected after each game (7-point scale) were analyzed using Mann-Whitney U tests. For enjoyment, there was no significant difference found between impulse and rate-based versions (Z=-0.87, p=0.38). This was a surprising finding because of the previous study's suggestion that the impulse-based version was more enjoyable than the rate-based version (section 4.4.5). For engagement, there was a significant difference (Z=2.12, p=0.034) in favor of the impulse-based version (although the absolute difference was small). Figure 6.4 shows post-game questionnaire results.

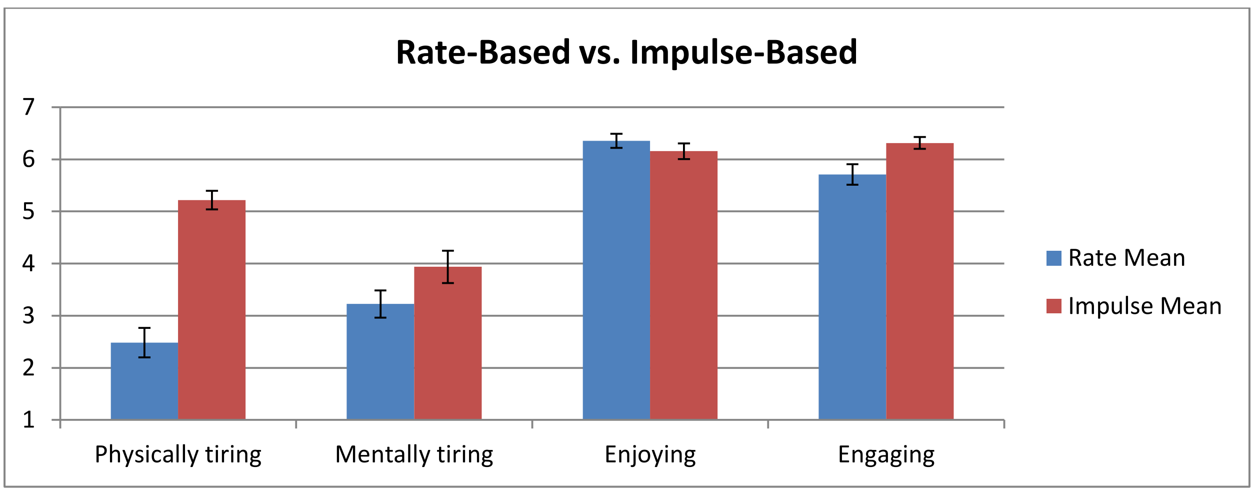

Figure 6.4: Results of post-game questionnaires (1-7 Likert scale) (± s.e.).

6.3.3 Results from Participant Zero

As a reminder, P0 was a special participant who played in both leagues and had more time playing each version of the game. Therefore, some insight may be gathered into how a player with more experience enjoyed and was engaged in each version.

In the post-study questionnaire, P0 enjoyed the impulse-based version more than the rate-based version. When asked ‘by how much,’ P0 rated a four, which suggests he slightly enjoyed the impulse-based version more. P0 also had similar data to the other participants in the post-game questionnaires. He rated enjoyment to be similar for both versions, but gave the impulse-based version a consistently higher engagement rating throughout the post-game questionnaires. The difference in engagement between the two versions was higher in P0’s ratings than the other participants. As P0 played more games, it is interesting to note that engagement levels are still high, if not higher, for him even after more time with the impulse-based version than the other participants. Figure 6.5 shows P0’s post-game questionnaire ratings.

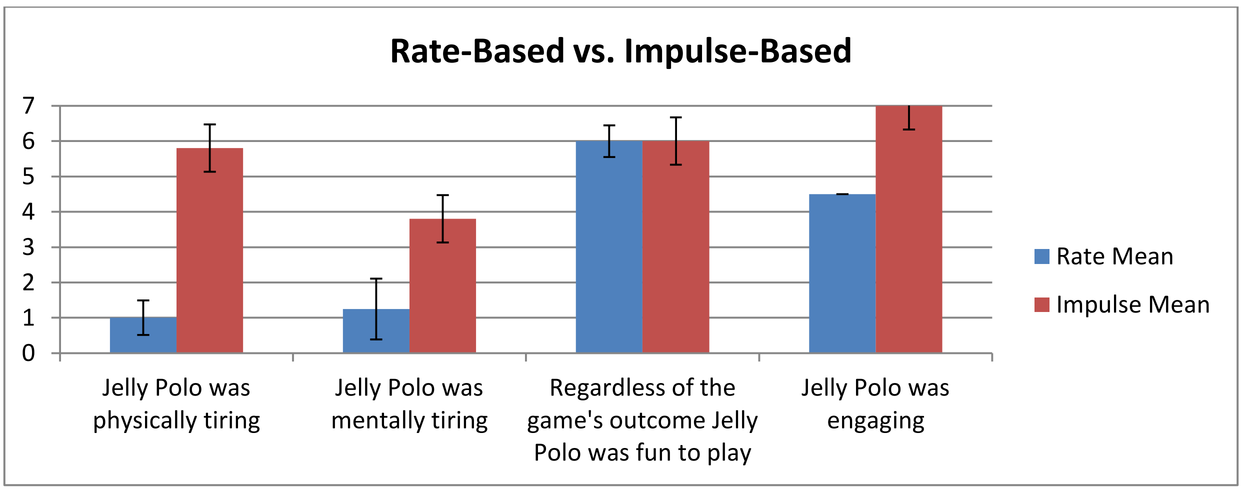

Figure 6.5: Results of P0’s post-game questionnaires (1-7 Likert scale) (± s.e.).

6.4 DISCUSSION

The third Jelly Polo study had three main findings:

- No significant difference was found in enjoyment levels between Jelly Polo with small-scale exertion (i.e., impulse-based version) and without small-scale exertion (i.e., rate-based version);

- Engagement levels were statistically higher, although only by a small amount, for Jelly Polo with small-scale exertion in all cases;

- Participants moved at 90% maximum speed, or higher, 60.2% in the rate-based version and only 0.53% in the impulse-based version.

In the following sections, we consider why these results were found.

6.4.1 Explanation for Results

From the previous studies in Chapters 4 and 5, small-scale exertion has the ability to add the benefits of expertise development, differentiation, and fatigue, so it would make sense that participants enjoyed the impulse-based version of Jelly Polo at least as much as the rate-based version. It is possible that participants were not exposed to the game enough to experience all the benefits of the impulse-based version to their full potentials. Participants played once a week compared to three times a week in the study conducted in Chapter 4, and games were only half as long. A participant from the previous study could have played as many as three hours of Jelly Polo in total. Whereas, in the current study, the most any player played, other than P0, was one hour.

We believe the decrease in the amount of play time may have had an influence on the enjoyment ratings. First, participants had less time to gain expertise development, especially since three games were played with rate-based controls where movement speed of the character could not be trained. Second, participants could not differentiate their skillsets as much because there was not enough time for teams to strategize and put participants in certain roles. Third, the fatigue factor could not be taken advantage of because teams did not have time to strategize for it. With Jelly Polo, there is a level of frustration players have with the controls when they first play the game because they are novel and comparatively difficult to rate-based controls. This means it takes a while (we hypothesize around 30 minutes to 1 hour) for players to get used to the controls and understand how to use them to their advantage.

It is also possible that with the short amount of time given, participants felt frustrated by the fatigue experienced in the impulse-based version. Given more time with the game, teams could learn to strategize against the fatigue and use it to their advantage. However, it is important to note that even with a possible increase in frustration with the impulse-based version, the enjoyment levels were similar compared to the rate-based version. It is possible that all the other factors of the impulse-based version added to an enjoyable experience. We suggest that if participants were given more time with the impulse-based game, they would learn how to use the fatigue aspect to their advantage and not see it as a frustration. This, in turn, could increase the enjoyment ratings. However, more research is needed to verify our suggestions.

There also may have been a difference in the enjoyment ratings between this study and the study in Chapter 4 because of the different types of relationships players had with each other. Participants from Chapter 4 were all from the same lab and had at least some form of relationship outside of the study. Participants in the current chapter may have been mostly strangers. Teams from Chapter 4 also played different teams throughout the week; teams from this chapter played the same team every session.

The lack of any strong difference in enjoyment between game versions suggests we can get the added benefits of small-scale exertion (i.e., expertise development, differentiation, and fatigue), while still providing an enjoyable play experience. Jelly Polo was also more engaging with small-scale exertion. Although the absolute difference was small, this result may suggest that participants were more immersed in the experience of playing with impulse-based movement than with rate-based movement. Perhaps playing Jelly Polo for longer periods of time would favor the impulse-based version because players are more engaged in the game.

The higher engagement scores that the impulse-based version of Jelly Polo received, compared to the rate-based version, may have arisen from the variability that is inherent in the control scheme. Game researchers have noted that games are more enjoyable and engaging when there is greater suspense about the outcome [2] – for example, Mueller states "uncertainty contributes to an element of suspense and facilitates surprise in games through random or chance events, which can play an important part in what makes a game engaging" [70]. The uncertainty that arises from the variability in the impulse-based control scheme (both in terms of individual differences, and in terms of changes over time) is one kind of randomness that may contribute to the positive engagement results.

The findings that rate-based players spent the majority of the game (60.2%) above 90% maximum speed, and that impulse-based players spent little time (0.53%) above 90% maximum speed, can be explained based on the differences between the control schemes. Players must use a high amount of effort to keep maximum speed for long durations with impulse-based controls. However, with rate-based controls, players can easily hold the movement stick down for long durations without getting tired. Linking back to TaFR, if players try to hold maximum speed using small-scale exertion, there is a decrease over time in power (i.e., speed) as shown in Figure 3.4. The gameplay in Jelly Polo does not require long durations of maximum speed, and thus in the impulse-based version players took advantage of situations where they could take breaks. The difference in maximal movement speeds can possibly be explained by small-scale exertion because this was the only aspect changed between game versions. There are, of course, situations where players do not need to hold maximum speed in the rate-based version as well (e.g., playing goalie), but we still see players spending the majority of the time at top speed.

6.4.2 Final Thoughts

From the first Jelly Polo study, we expected that Jelly Polo with impulse-based controls would be more enjoyable than with rate-based controls (see Section 4.4.5). We found, however, that there was no significant difference in enjoyment between both versions, but engagement was significantly higher in the impulse-based version. The fact that engagement was slightly higher gives further evidence that small-scale exertion can improve sports video games. If the same game can have the added benefits of increased expertise development, increased differentiation, and increased engagement, all while maintaining a similar level of enjoyment, then this is an interesting direction for sports video games. More research is needed, but this is a good starting point for the next round of studies.

CHAPTER 7

GENERAL DISCUSSION, FUTURE WORK, AND CONCLUSIONS

This chapter provides a general discussion of why we found what we did, ways that the work can be generalized, and study limitations. This chapter also presents several recommendations for future work, a list of accolades Jelly Polo has received, and finishes off with a final summary and conclusions.

7.1 GENERAL DISCUSSION

7.1.1 Reasons for Results

Exergames have recently gained attention because of the popularity of new input devices which have the ability to capture full-body movements. Many designers have tried to come up with compelling game designs in order to leverage this technology. However, very few of these types of games have been well received, such as the "All-Play" series of games discussed in section 2.3. We believe it is because the use of these new technologies requires too much of the user. They need to have a lot of extra space around the play area; they are required to expend short bursts of high amounts of energy while playing (in most cases); and they are commonly forced to buy and even wear some of these input devices while they are playing. This takes away from the traditional game environment while also creating a barrier for some users who do not have the extra money or physical ability to participate. Aside from weak attempts at creating an exergame which fits into the traditional game environment (e.g., the Olympic games), there has not been much of an effort to focus on physical competition using a standard game controller. We have created such a game which is also enjoyable and engaging.

Sports are synonymous with physical competition, but sports video games have become battles of statistical chance and simulations. There have always been unbalanced video game characters to choose in competitive games. One of the earliest examples of this is Bo Jackson from the 1991 football game *Techmo Super Bowl*. Bo Jackson in this game could run circles around every other character. The in-game Bo Jackson character was given the ability, by the developers, to have a higher speed than any of the other characters. This leads to a huge advantage, or disadvantage for the other team, if you play with that character. Another example of this, that is well-known throughout the video game community, would be Oddjob in the Nintendo 64 game *GoldenEye*. This game is a 3D first person shooter where players have the option to play against one another in a multiplayer deathmatch. Oddjob is the only character in the game that is much shorter than all of the other characters. This makes it so players have to manually aim downwards to aim at Oddjob, whereas all other characters can be hit without changing the neutral aim position. The verbal rule "No Oddjob!" became famous because of this [1]. Occurrences like these can frustrate players and make games seem less of a balanced competition.

A game like Jelly Polo, with small-scale exertion, guarantees that there can be no unbalanced character choices between the teams. The characters in the game are directly related to the player, and any skill involved is due to player skill, not statistical simulations. This is one of the main attractions of Jelly Polo; players can compete in a sport-like fashion against the opposing team's players, not characters. This is one of the first physically competitive and sport-like sports video games. We saw expertise development in player skill because we created an input mechanism that allows for physical improvement over time. Traditional rate-based controls simply do not allow for this type of gain in speed due to player expertise. In Jelly Polo, not only do players add physiological skill (e.g., can flick thumb faster and longer), but they also increase their team strategies (e.g., knowing where to go on offense or defense, when to pass, when to shoot, etc.) which is very sport-like. Every player had individual differences in terms of movement and passing skill. This goes beyond the mental ability and strategy to know when to attack, when to defend, when to pass, and when not to do these things; players differed in their ability to *perform* all of these actions. This allows players to have different skill sets, much like in real-world sports, where all players are different in their own way. Fatigue was also apparent to every player that played Jelly Polo. Although we did not see it in the long-term performance data, most likely due to player strategies to counterbalance it, we did see it in the short-term and we found the strong observation of not being able to play above 90% max speed in the impulse-based version compared to the rate-based version.

When players spent more time playing the impulse-based version of Jelly Polo, they enjoyed it more; this is shown from observations made in Chapter 4 and from P0's data in Chapter 6. We feel this is because there is a difficulty barrier that has to be overcome before one can enjoy Jelly Polo's gameplay to its full potential. At the beginning, players feel somewhat frustrated because the controls are very different from what they are used to. However, over time this allows for a much more interesting experience.

7.1.2 Generalizability

Small-scale exertion works well in the genre of sports video games because exertion is a common factor in all sports. Although, our main implementation for small-scale exertion was using character movement and this type of movement can be found in almost all genres of video games. Therefore, small-scale exertion may be able to fit in all genres of video games. Of course, designers could add small-scale exertion to any video game, but some games would benefit more from it than others. As an example, a fighting game could use small-scale exertion in movement and in power of attack (e.g., punches). If we could make a controller that senses differences in the amount of pressure a button press takes, we could map it to punch power (i.e., pressing the button harder performs a harder punch). This may be a possible design for fighting games, but there is no telling if this will make them more enjoyable. Another example would be to use impulse-based movement in an open-world game like *Minecraft*. In *Minecraft* players traverse a world collecting materials to be able to build their own unique objects or buildings. There are many examples of huge areas players have built over hundreds of hours, but impulse-based movement could change gameplay. It is not known how gameplay would change, but one possibility is that player-built areas would be much closer together because players would have a harder time moving further away due to the movement mechanic. Again, it is unknown at the moment if this would make the game more enjoyable, or gain some other benefits, but it is definitely a way the game could be changed.

eSports would be a great arena to showcase these types of games. We have created a game, Jelly Polo, which is based on competition of player skill. It can be argued that a sports video game like Jelly Polo, with small-scale exertion, is similar to a real sport which could bring the sports genre into eSports, where most people would imagine it belongs. The current findings could form a whole new genre of video games. The new genre would be an extension of regular sports games, but the player becomes the in-game character and the skills of the player are the only factors of the outcome of a game. The level of sport-like challenge can increase the competitive nature of sports video games and bring in a whole different type of gamer to them. Instead of mainly sports fans playing sports video games [59] that are largely based on simulations of the real thing, competitive video game players will have a chance to compete, train, and become the best at a video game that is based on a player's physical and mental abilities.

We feel physicality can be added to any genre of game, but designers need to be very careful in the method in which they add the physicality. We have learned a lot from our experience creating these small-scale exertion games and studying them. Below is a list of limitations we have found with our studies that we hope other researchers can learn from.

7.1.3 Limitations

Our TaFR study and our first Jelly Polo study had the same limitation which was using participants from our own research lab. The TaFR study focused on low-level exertion data, so we believe that familiarity with the participants was not a major bias. Future work should replicate our studies with a wider variety of participants. Our second Jelly Polo study had the limitation of always performing the impulse-based tasks first before performing the rate-based tasks. We believe this limitation changes little of the results found. The fact that rate-based causes little to no fatigue and we gave breaks between tasks should lead to the conclusion that there was no biasing effect. To be sure, future researchers should counterbalance their study trials. Our final Jelly Polo study had some limitations as well. First, we did not sustain constant team members throughout the entire study. This lowered the likelihood of teams bonding and creating better strategies, as well as led to an inability to track expertise development of each player. Since we were only tracking enjoyment and engagement ratings, and we only used data from participants participating in more than half of the allotted games, we feel this is not a major issue. Researchers should focus on maintaining consistent teams throughout their studies. The second limitation was that players only had one session a week and played for shorter amount of time than in the previous study. This may have impacted our results. We suggest this led to subjective ratings being biased due to the fatigue being seen as a frustration rather than a gameplay element in the impulse-based version. Although, we did get similar enjoyment ratings for both game versions, we suggest more and longer sessions would lead to the same feelings as in the first Jelly Polo study (i.e., impulse-based is more enjoyable than rate-based).

7.2 FUTURE WORK

We have many suggestions for future work in this area. Since this is the first exploration into small-scale exertion in video games, there are many directions researchers can take. Below are five suggestions.

7.2.1 Impulse-Based vs. Rate-Based Leagues

Our third Jelly Polo study had a comparison between the impulse-based version and the rate-based version. However, there were limitations to the study. For future work we hope researchers would make a more structured study to get more robust results. We suggest using two completely separate leagues (one using only impulse-based and one using only rate-based controls), making sure teams are consistent (i.e., no changing of players), and having more and longer sessions similar to our first Jelly Polo study. We feel this would give better results to compare the two versions. With consistent teams, quantitative data could also be taken to track improvements, differentiation, and fatigue in a real game situation.

7.2.2 Differing the Amount of Practice

It would be interesting to see how much better teams could become with more practice than other teams. For this study, we suggest using training tasks similar to our third Jelly Polo study to train some teams. The other teams would get less or no training at all. Then let them play against each other and see if the training has any effect on in-game skill. This could determine the importance of adding a training section to the game so players can practice outside of playing actual games.

7.2.3 Different Age Groups

During the time of our research, we had younger children (8-13 years old) from science camps come to our lab and play Jelly Polo. This was a very interesting experience to see how different these younger players played compared to our regular participants which were usually 10 years older. The children played Jelly Polo very much like their age group plays hockey in real life: they all chased the ball around in one big crowd. This is a common belief of how young children play certain sports and it was interesting to see them control the game in a similar manner. Therefore, it would be interesting to see how different age groups play a small-scale exertion game like this. There may be some correlation in the way they play the game to the way they play in the real world.

7.2.4 Implementing Small-Scale Exertion in a Modern Sports Video Game

Another step would be to use the same kind of small-scale exertion mechanics in a game using high-end graphics of human avatars. This could be implemented by using the graphics from the latest NHL or FIFA game and changing the movement and passing mechanics. More complicated physics and movement animations may need to be added, but this would give a good idea if this type of control scheme could be implemented into modern sports video games.

7.2.5 Local vs. Online Play

The last suggestion for future work could be implemented in any version of the game (2D or 3D). One of the biggest advantages Jelly Polo has is being able to play with all six people sitting side-by-side. This allows for a great dynamic within and between teams. We have always imagined how gameplay would change if players were not in the same room. Researchers could have each team in a separate room or each individual player in a separate room. This could determine the differences of this game as an online multiplayer game as opposed to a completely local game.

7.3 JELLY POLO ACCOLADES

Over the course of our research, we refined Jelly Polo to the point of it being a very entertaining game as well as being a good research tool. Because of this, the game has been featured in a gamejam event in Waterloo, Ontario, and we have entered Jelly Polo in five game competitions. Most notably, we entered into the Student Game Competition for the CHI Play 2014 conference. This was an international competition and Jelly Polo won the Audience Choice Best Game Award. This meant out of all the other games (around 20 others), Jelly Polo got the most votes from the attendees of the conference as the best game. Currently, Jelly Polo is entered into the Student Game Design Contest for CHI 2015. We were told by reviewers that the game was in the top three in the innovative design section of the competition.

7.4 CONCLUSIONS

The problem addressed in this thesis was stated as follows: sports video games are not very sport-like or competitive when playing with traditional rate-based controls. The present research has shown that traditional sports video games have three drawbacks: limited expertise development, individual differentiation, and fatigue. This is mostly due to the control scheme which is rate-based and the use of statistical simulations to control much of the game's outcomes. Exergames used currently also have drawbacks in that they do not use the traditional game environment, are full-body and require high amounts of exertion for short amounts of time leading to breaks in gameplay. One possible solution to these difficulties is to use small-scale exertion. This method requires the design of an input mechanic that requires only the use of hands and fingers (or feet). This approach allows the use of the traditional game environment and is a viable solution to the drawbacks of sports video games stated above; thus creating a game which is competitively based on player skill and sport-like.

7.4.1 Summary of Thesis

This thesis focused on the creation of two new small-scale exertion sports video games. The first game, Track and Field Racing, was an initial look into the simplest form of a small-scale exertion game to determine the viability of this type of game. Track and Field Racing gave us good initial results in terms of individual differentiation and fatigue using small-scale exertion controls. Players got tired over the course of a race and could not keep up top speed throughout. Each player also had a different skillset in terms of speed, endurance, and timing.

The second game, Jelly Polo, which was the main focus of this research, uses a control scheme which can be used in the traditional game environment where players sit in front of a display and hold regular controllers. Three studies were performed using Jelly Polo. The first was a qualitative look into solving the three drawbacks of sports video games (i.e., limited expertise development, differentiation, and fatigue). All of these three drawbacks were addressed using our control scheme. Expertise development was observed through the skill levels of the players in terms of movement and passing, individual differentiation was observed through different tactics and skills obtained by each player, and fatigue was observed through subjective questionnaires and observations of the participants. The second study using Jelly Polo quantified expertise development, individual differentiation, and fatigue through structured skill tasks over multiple sessions. Expertise development and individual differentiation were apparent in the results, but fatigue was only apparent in the short-term (within tasks) and subjectively. Other quantitative factors such as playing above 90% maximum speed suggest that fatigue is apparent. Rate-based controls were also found to not allow expertise development or individual differentiation between players. The third study compared two versions of Jelly Polo, one with small-scale exertion and one without. We found that the small-scale exertion version of the game was similar in enjoyment and significantly more engaging than the non-small-scale exertion version. This suggests a game with small-scale exertion addresses the three drawbacks while also being more engaging, and just as enjoyable, as the same game with traditional movement controls.

7.4.2 Summary of Contributions

The primary contribution of the present research is the novel exploration into small-scale exertion, specifically pertaining to its effectiveness in sports video games.

The research also made several secondary contributions:

- The development of two small-scale exertion games – Track and Field Racing and Jelly Polo. TaFR demonstrated a simple form of small-scale exertion, and Jelly Polo showed a more advanced form of a small-scale exertion game.
- The first empirical baseline results of player performance over time using traditional rate-based controls.
- The first empirical baseline results of player performance over time using small-scale exertion controls.
- The first comparison between traditional rate-based controls and small-scale exertion controls in terms of expertise development, individual differentiation, fatigue, enjoyment, and engagement.

7.4.3 Concluding Remarks

The problem in this thesis was that sports video games are not very sport-like or competitive when playing with traditional rate-based controls. The solution presented here was to use small-scale exertion to add physicality to the traditional game environment. Small-scale exertion was accomplished by adding impulse-based movement and precision passing to a sports video game. The present research showed that small-scale exertion can address the three drawbacks inherent in traditional sports video games: limited expertise development, low individual differentiation, and lack of fatigue. The present research also showed that small-scale exertion created a more engaging experience, while providing similar enjoyment levels, compared to a rate-based version. By examining the current state of exergames and sports video games, by developing and evaluating two new small-scale exertion games, and by comparing them to traditional games, this research revealed new effective and feasible mechanisms to add to the experience of sports video games; thus opening up new opportunities for the creation of sports video games that are more competitive and more like real-world sports.

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APPENDIX A

TRACK AND FIELD RACING STUDY

A.1 Demographic/Questionnaire Form

Name:_________________________

Age:________

How many hours a week do you play sports:____________

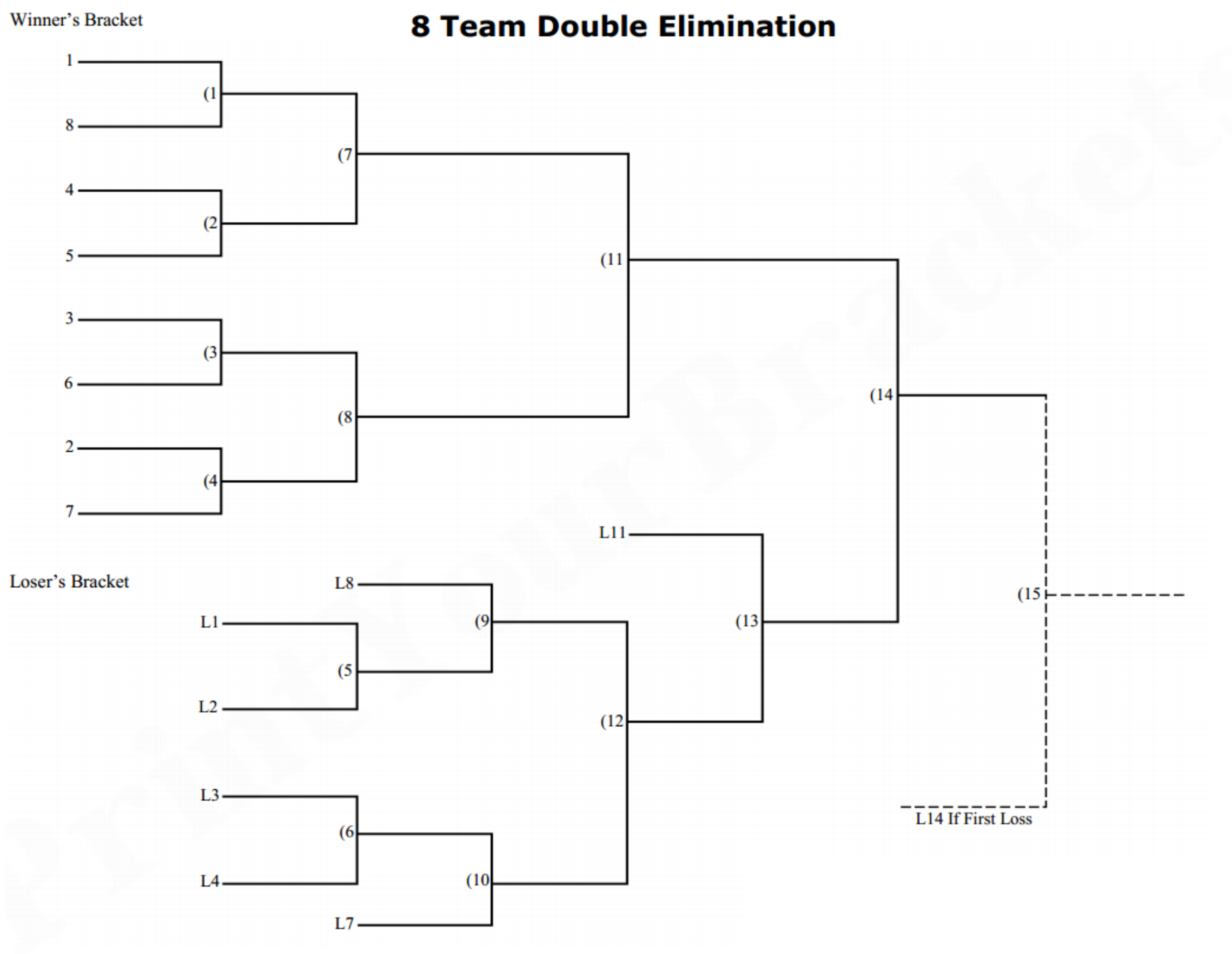
How many hours a week do you play computer games:__________

How many hours a week do you play console games:___________

How many hours a week do you play sports video games:________

Have you ever played physical games (exergames): Yes No

A.2 Double Elimination Tournament Bracket



APPENDIX B

JELLY POLO STUDY 1

B.1 Post-League Questionnaire

Name:______________________________

Jelly Polo was fun:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo was frustrating:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I looked forward to playing Jelly Polo on game days:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I would enjoy playing Jelly Polo outside of the lab:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo was physically tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo was mentally tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo made my thumb sore:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I played more offense than defense:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I passed more than I shot:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I tried to win every faceoff:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
My team had a set strategy:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7

I liked playing goalie:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo is a sport:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I knew which player was which	Disagree			Neutral			Agree
number on my team:	1	2	3	4	5	6	7
I knew which player was which	Disagree			Neutral			Agree
number on the other team:	1	2	3	4	5	6	7
I kept track of my stats:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I kept track of my team's stats:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I tried hard to be the top in a	Disagree			Neutral			Agree
certain stat:	1	2	3	4	5	6	7
I got better at Jelly Polo over time:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7

Which Sport is Jelly Polo most like (order from 1-5, 1 being most alike):
Basketball __
Soccer __
Hockey __
Volleyball __
European Handball __ (leave this empty if you don't know what sport this is)
Other______________ __

For the questions below, if you can't think of any specific player just leave it blank.
Which team did you not like to play against the most: _____________________

Which player did you not like to play against the most: _____________________

Who was the fastest player (don't pick yourself): ____________________

Who was the best at handling the ball (don't pick yourself): __________________

Who was the best at scoring (don't pick yourself): ____________________

Who was the best passer (don't pick yourself): ____________________

Who was the best at winning faceoffs (don't pick yourself): ____________________

Who was the best goalie (don't pick yourself): ____________________

If you could play on one specific players team, who would it be: ____________________

B.2 Post-League Interview Questions

What was the best part about Jelly Polo?

What was the worst part about Jelly Polo?

Did your thumbs get tired playing?

What was your team's strategy? Did it every change throughout the league or for different teams?

Did the thumb movement have an effect on your strategy?

Did which side you were on make any difference?

Did which color you were make any difference?

Did which number you were make any difference?

Did you get better at playing over time? How?

Did the week break have any effect on how you played afterwards?

Did you like having all the stats available?

Did having the stats available change how you played?

What did you think of each different team? 1? 2? 3? 4?

Would you keep playing Jelly Polo? In the lab or outside of the lab?

Did you play differently if you were winning or losing by a large margin?

Did you ever talk about Jelly Polo to anyone when you weren't playing? Who?

Anything else?

APPENDIX C

JELLY POLO STUDY 2

C.1 Consent Form

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

Research Project: **Jelly Polo Movement and Passing Study**

Investigators: Dr. Carl Gutwin, Department of Computer Science (966-8646)

Mike Sheinin, Department of Computer Science

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is concerned with detecting **expertise development in small-scale exertion tasks**.

The goal of the research is to **examine the effects of small-scale exertion on moving and the effects of precision passing on expertise development**.

The study will require **90** minutes spread over three sessions, during which you will be asked to **complete movement tasks including races and obstacle courses, and a passing task** in the Human-Computer Interaction Lab at the University of Saskatchewan.

At the end of the session, you will be given more information about the purpose and goals of the study, and there will be time for you to ask questions about the research. As a way of thanking you for your participation and to help compensate you for your time and any travel costs you may have incurred, you will receive a **$15** honorarium at the end of the session.

The data collected from this study will be used in articles for publication in journals and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. This summary will be available on the HCI lab's website: **http://www.hci.usask.ca/**

All personal and identifying data will be kept confidential. Confidentiality will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. Do you have any questions about this aspect of the study?

You are free to withdraw from the study at any time without penalty and without losing any advertised benefits. Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. Your right to withdraw data from the study will apply until results have been disseminated, data has been pooled, etc. After this, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Carl Gutwin, Professor, Dept. of Computer Science, (306) 966-8646, gutwin@cs.usask.ca

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Carl Gutwin, Professor, Dept. of Computer Science, (306) 966-8646, gutwin@cs.usask.ca
- Research Ethics Office, University of Saskatchewan, (306) 966-2975 or toll free at 888-966-2975.

Participant's signature:____

Date:____________________

Investigator's signature:____

Date:____________________

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Research Ethics Office at the University of Saskatchewan.

C.2 Demographic Form

*Required

Participant ID *

Age *

Sex *

- Male
- Female

Handedness *

- Left
- Right

How much time do you spend playing video games? *

PC, Console, Mobile, etc.

- None
- Less than 3 hours a week
- 3-7 hours a week
- 1-2 hours a day
- More than 2 hours a day

Which system do you primarily play video games on? *

- Console (Xbox, PlayStation, Wii, etc.)
- Computer/PC

Rate your prior experience with a video game controller *

1 2 3 4 5 6 7

I've never used them ◯ ◯ ◯ ◯ ◯ ◯ ◯ I'm an expert

How often do you use the thumbsticks when you play video games with a controller? *

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

How often do you play competitive multiplayer games? *

(e.g., Call of Duty multiplayer, Halo multiplayer, League of Legends, NHL/NBA/FIFA/NFL online, etc.)

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

Are you a sports fan? *

Watch/play real world sports

- ◯ Yes
- ◯ No

How much time do you spend playing sports video games? *

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

Submit

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C.3 Impulse-Based Questionnaire

For the questions below, rate your agreement with each statement pertaining to impulse based tasks completed today only:

*Required

Participant ID *

The tasks were mentally demanding *

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

The tasks were physically demanding *

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

My thumb/hand/wrist got tired during the tasks *

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

I feel like I got better at moving the character *
Speed, technique, etc.

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

I think I can still improve on moving the character *
Speed, technique, etc.

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

I was successful in accomplishing the tasks *

	1	2	3	4	5	6	7	
Disagree	◌	◌	◌	◌	◌	◌	◌	Agree

I worked very hard to accomplish my level of performance *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

Submit

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C.4 Rate-Based Questionnaire

For the questions below, rate your agreement with each statement pertaining to impulse based tasks completed today only:

*Required

Participant ID *

The tasks were mentally demanding *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

The tasks were physically demanding *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

My thumb/hand/wrist got tired during the tasks *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel like I got better at moving the character *
Speed, technique, etc.

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I think I can still improve on moving the character *
Speed, technique, etc.

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I was successful in accomplishing the tasks *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I worked very hard to accomplish my level of performance *

1 2 3 4 5 6 7

Disagree	○	○	○	○	○	○	○	Agree

Submit

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C.5 Passing Questionnaire

For the questions below, rate your agreement with each statement pertaining to the passing task completed today only:

*Required

Participant ID *

The task was mentally demanding *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

The task was physically demanding *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

My thumb/hand/wrist got tired during the task *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel like I got more accurate at passing the ball *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I think I can still improve on my accuracy passing the ball *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I was successful in accomplishing the task *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I worked very hard to accomplish my level of performance *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

Submit

Never submit passwords through Google Forms.

C.6 Post-Study Questionnaire

The following questions pertain to your ENTIRE experience with the Jelly Polo study

-Impulse = Flicking the stick to move

-Rate = Holding the stick down to move

*Required

Participant ID *

[ ]

Which control type was more mentally demanding? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type was more physically demanding? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type was more fun? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type was more boring? *

	1	2	3	4	5	6	7

Impulse	○	○	○	○	○	○	○	Rate

Which control type was more frustrating? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type was more challenging? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type would you prefer to use when playing video games? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Which control type would you prefer to use when playing sports video games? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

If you wanted to get better at a video game, which control type would best allow for this? *

	1	2	3	4	5	6	7	
Impulse	○	○	○	○	○	○	○	Rate

Impulse (Flick Movement)

For the questions below, rate your agreement with each statement. The questions pertain to the impulse based control type over the course of the entire study:

I feel like I got FASTER overall at moving my character using the impulse based controls *

(i.e. Speed of the character over the entire study)

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel that I could still get FASTER at moving my character using impulse based controls *

(i.e. Speed of the character)

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel like I got better overall at CONTROLLING my character using the impulse based controls *

(e.g., Moving around obstacles)

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel that I could still get better at CONTROLLING my character using impulse based controls? *

(e.g., Moving around obstacles)

1 2 3 4 5 6 7

Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ Agree

In the obstacle courses, I sometimes felt like my time increased (got worse) because my thumbs/hands got tired and I moved my character slower using impulse based controls? *

1 2 3 4 5 6 7

Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ Agree

Rate (Hold/Regular Movement)

For the questions below, rate your agreement with each statement. The questions pertain to the rate based control type over the course of the entire study:

I feel like I got FASTER overall at moving my character using the rate based controls *

(i.e. Speed of the character over the entire study)

1 2 3 4 5 6 7

Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ Agree

I feel that I could still get FASTER at moving my character using rate based controls *

(i.e. Speed of the character)

1 2 3 4 5 6 7

Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ Agree

I feel like I got better overall at CONTROLLING my character using the rate based controls *

(e.g., Moving around obstacles)

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I feel that I could still get better at CONTROLLING my character using rate based controls? *

(e.g., Moving around obstacles)

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

In the obstacle courses, I sometimes felt like my time increased (got worse) because my thumbs/hands got tired and I moved my character slower using rate based controls? *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

Passing

For the questions below, rate your agreement with each statement. The questions pertain to the passing task over the course of the entire study:

I feel like I got more accurate overall at passing *

	1	2	3	4	5	6	7	
Disagree	○	○	○	○	○	○	○	Agree

I would like to play sports video games with the style of passing used in this study *

	1	2	3	4	5	6	7	
Disagree	○	○	●	○	○	○	○	Agree

Submit

Never submit passwords through Google Forms.

C.7 Study Script

Setup

- Have one controller connected
- Have study version of Jelly Polo running in full screen
- Have demographics and study questionnaires ready on laptop or second display
  - Demographics, Impulse, Rate, Passing
- Have 2 copies of the signed consent form ready
- Have notebook and pen ready to record observations from gameplay, important comments, and signs of frustration or fun.

Introduction

- Give consent form
  - "You will get $15 at the end of the final session for participating, and are free to withdraw from the study at any time, no questions asked and you can still collect the money. Your data will also be removed from any analysis."
  - Collected data will be used in academic publications and other publicly available information: we will not use any identifying information
- Get them to fill out demographic form (online)
- Explain: "We are testing differences in control styles for moving a 2D character with a controller. We are also looking into precision passing. Basically I will ask you to do a number of simple tasks using different control styles. These will all be explained throughout the study
- Any questions?
- Hand them the controller

Study

- **Press 'Space'**
- Explain: "The first part of the study will be using Impulse-based movement. To move your character you flick the left stick in the direction you want to move. The faster you flick the stick, the faster your character moves. I'll let you practice a bit to get used to it"
- Wait like 20 seconds or until they think they understand it
- **Press 'Space'**
- Explain the race: "Now you will run a race. You will start behind the white line on the left and a countdown will start. When the countdown ends, you will race to the right side line, basically the wall, then come back past the red line to the left as fast as you can. The white line on the right will change color to green once you touch it. Make sense?"

- When they understand, **Press 'Space'**
- Once finished the race, **Press 'Space'**
- Explain the obstacle course: "Now you will run an obstacle course. You will start in the circle and after a countdown, you will follow the arrows around the obstacles. So go above this obstacle, below this one, above this one, etc. Then after the last one, touch the circle. Try to do this as fast as possible. If you touch the obstacle, you will just bounce back. You will do the obstacle ten times in a row with a few seconds break in between each one. Do you understand?"
- When they understand, **Press 'Space'**
- Once finished the obstacle courses, **Press 'Space'**
- "Now you will run one more race, let me know when your thumbs feel okay to go"
- Wait no more than 30 seconds, **Press 'Space'** when they are ready
- Once done, have them fill out the Impulse Questionnaire (online)
    - Either click off to the other screen or Alt+tab (DO NOT CLOSE JELLY POLO)
- Once done, click back to the jelly polo program and **Press 'Space'**
- Explain Rate based: "Now we will do the same thing you just did, but with rate based movement. This is like most games where you can just hold the stick to move. Take a little bit to get used to the controls"
- When they are ready, **Press 'Space'**
- Explain: "Now you will run another race, ready?"
- When ready, **Press 'Space'**
- Once done, **Press 'Space'**
- Explain: "Now you will run the same obstacle courses, ready?"
- When ready, **Press 'Space'**
- Once done, **Press 'Space'**
- Explain: "Now another race, ready?"
- When ready, **Press 'Space'**
- Once done, have them fill out the Rate Questionnaire (online)
    - Either click off to the other screen or Alt+tab (DO NOT CLOSE JELLY POLO)
- Once done, click back to the jelly polo program and **Press 'Space'**
- Explain passing: "Now we are finished with the movement part. Now we are just going to do a passing task. Passing is done with the right stick. You will be given a ball and we want you to try to pass to this moving target as accurately as possible. To pass you flick the right stick in the exact direction you want the ball to go. You have to flick it a little hard or else it will stay in your arm. If you hit the obstacle, it will turn green, but the goal is just to get as close as possible. This task is not based on time, so take as long as you want. We just want you to be as accurate as possible. You will be given five attempts at this target, and then it will move up here (point) and move like this. You get five tries at this target, then it will move to the left (point), then the bottom. You get five attempts at each target, so just try to hit it as many times as you can. The

target will move around you three times, moving farther away each time around. Does that make sense?"

- When ready, **Press 'Space'**
- Once finished, have them fill out the Passing Questionnaire (online)
- They are finished after this.
- Thanks to participants and remind them of next scheduled appointment. Say they will do the exact same tasks then as well.

APPENDIX D

JELLY POLO STUDY 3

D.1 Consent Form

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

Research Project: **Effects of Exertion in the Small and Enjoyment**

Investigators: Dr. Carl Gutwin, Department of Computer Science (966-8646)

Mike Sheinin, Department of Computer Science

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is concerned with **differences in enjoyment between control styles of a sports video games**.

The goal of the research is to **gain knowledge about how players enjoy different control styles of sports video games**.

The study will require **6** minutes a week, during which you will be asked to **play Jelly Polo with different control styles** in the CMPT 106 tutorials at the University of Saskatchewan.

At the end of the session, you will be given more information about the purpose and goals of the study, and there will be time for you to ask questions about the research. As a way of thanking you for your participation and to help compensate you for your time and any travel costs you may have incurred, you will receive some **course credit** at the end of the session.

The data collected from this study will be used in articles for publication in journals and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. This summary will be available on the HCI lab's website: **http://www.hci.usask.ca/**

All personal and identifying data will be kept confidential. Confidentiality will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. Do you have any questions about this aspect of the study?

You are free to withdraw from the study at any time without penalty and without losing any advertised benefits. Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. Your right to withdraw data from the study will apply until results have been disseminated, data has been pooled, etc. After this, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Carl Gutwin, Professor, Dept. of Computer Science, (306) 966-8646, gutwin@cs.usask.ca

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Carl Gutwin, Professor, Dept. of Computer Science, (306) 966-8646, gutwin@cs.usask.ca
- Research Ethics Office, University of Saskatchewan, (306) 966-2975 or toll free at 888-966-2975.

Participant's signature:____

Date:____________________

Investigator's signature:____

Date:____________________

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Research Ethics Office at the University of Saskatchewan.

D.2 Post-Game Questionnaire

Name:______________________________ Rate-based:_____ or Impulse-based:_____

Jelly Polo was physically tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo was mentally tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Regardless of the game's outcome	Disagree			Neutral			Agree
Jelly Polo was fun to play:	1	2	3	4	5	6	7
Jelly Polo was engaging:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7

D.3 Post-League Questionnaire

Name:______________________________

Rate-Based Version:

	Disagree			Neutral			Agree
Jelly Polo(R) was fun:	1	2	3	4	5	6	7
Jelly Polo(R) was frustrating:	1	2	3	4	5	6	7
I looked forward to playing Jelly Polo(R) on game days:	1	2	3	4	5	6	7
I would enjoy playing Jelly Polo(R) outside of the lab:	1	2	3	4	5	6	7
Jelly Polo(R) was physically tiring:	1	2	3	4	5	6	7
Jelly Polo(R) was mentally tiring:	1	2	3	4	5	6	7
Jelly Polo(R) made my thumb sore:	1	2	3	4	5	6	7
I played more offense than defense:	1	2	3	4	5	6	7
I passed more than I shot:	1	2	3	4	5	6	7
I tried to win every faceoff:	1	2	3	4	5	6	7
My team had a set strategy:	1	2	3	4	5	6	7
I liked playing goalie:	1	2	3	4	5	6	7
Jelly Polo(R) is a sport:	1	2	3	4	5	6	7
I got better at Jelly Polo(R) over time:	1	2	3	4	5	6	7

Impulse-Based Version:

Jelly Polo(I) was fun:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo(I) was frustrating:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I looked forward to playing Jelly	Disagree			Neutral			Agree
Polo(I) on game days:	1	2	3	4	5	6	7
I would enjoy playing Jelly Polo(I)	Disagree			Neutral			Agree
outside of the lab:	1	2	3	4	5	6	7
Jelly Polo(I) was physically tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo(I) was mentally tiring:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo(I) made my thumb sore:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I played more offense than defense:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I passed more than I shot:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I tried to win every faceoff:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
My team had a set strategy:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I liked playing goalie:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
Jelly Polo(I) is a sport:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7
I got better at Jelly Polo(I) over time:	Disagree			Neutral			Agree
	1	2	3	4	5	6	7

Regardless of the outcomes of the games, which version of Jelly Polo did you enjoy playing more?

Rate-based:_____ or Impulse-based:_____

By how much: Rate-Based | Impulse-Based

O O O | O O O

A lot | A lot

More than Impulse Based | More than Rate Based

D.4 Study Script

- Get teams to sit down.
- Odd weeks, lower numbered team is Yellow
- Run game FULL SCREEN

- First game:
  - Press ‘1’
- Second game:
  - Press ‘2’

- Press ‘r’ for Rate-based OR ‘i’ for impulse based
- Make sure they are correct
- Press ‘s’ to start

- Press ‘p’ every once in a while to print log info to file

- At halftime press ‘h’

- When game is done, press ‘q’

APPENDIX E

JELLY POLO VIDEO LINKS

E.1 YouTube Links

Jelly Polo - First ever league game: https://www.youtube.com/watch?v=Ul4DLzPEIkQ

Jelly Polo - Last playoff game of first JP league: https://www.youtube.com/watch?v=tUlTx8Ml-W0

Jelly Polo Highlights Full: https://www.youtube.com/watch?v=Tzy-SljRjZ0

Jelly Polo Top 10 Video: https://www.youtube.com/watch?v=MhquVbtp7dI

CHI 2014 Exertion in the Small: https://www.youtube.com/watch?v=wX60Xk1UofE

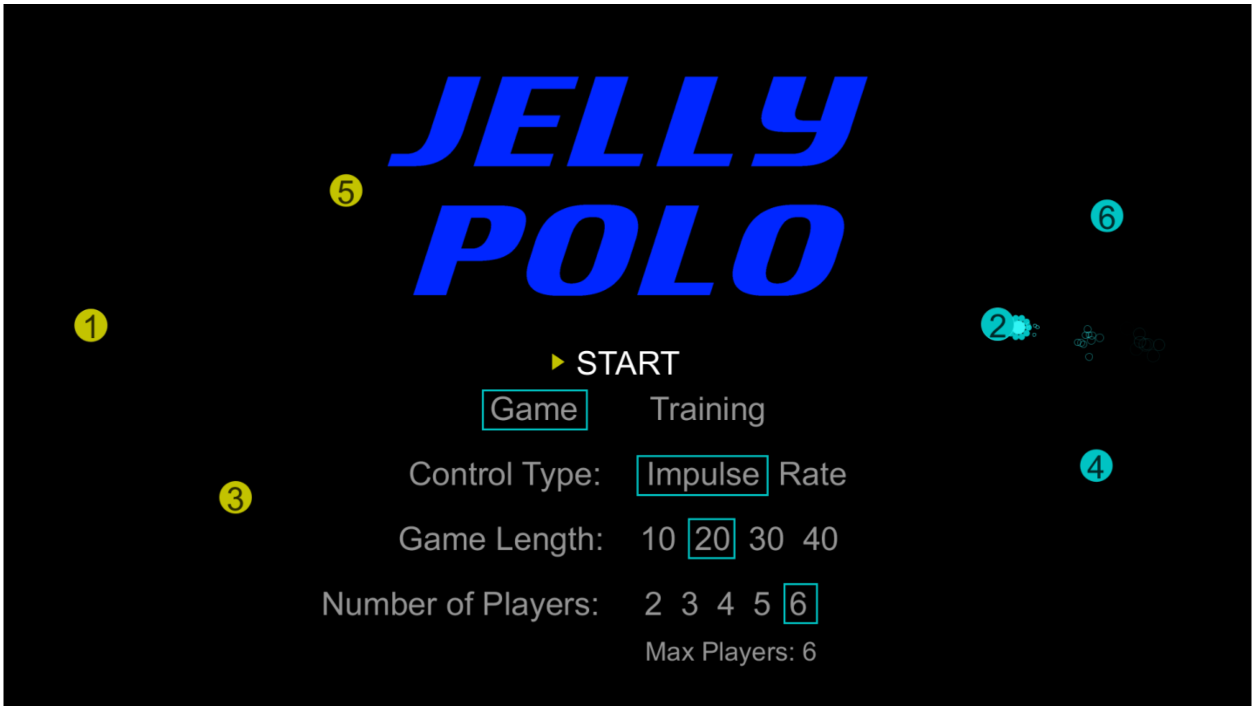
Jelly Polo Chi Play Video: https://www.youtube.com/watch?v=U-tEU-lVArE

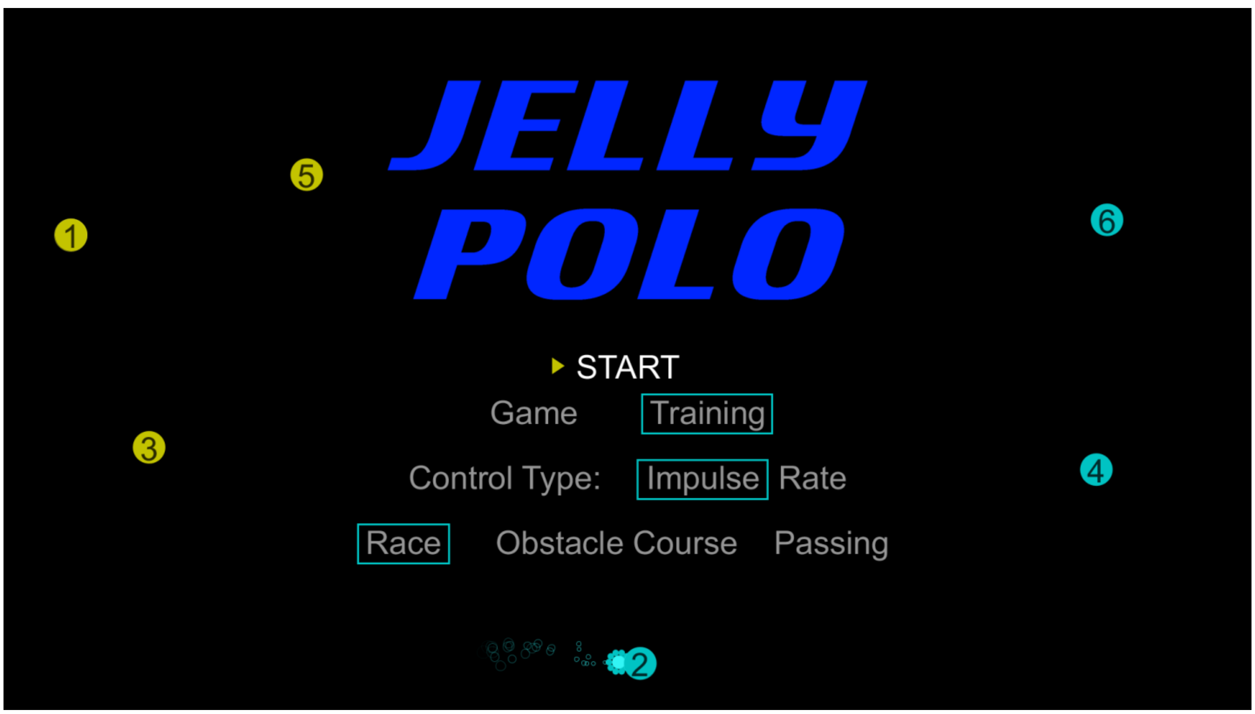
Jelly Polo SurfNet 2014 Minute Madness: https://www.youtube.com/watch?v=rVV5eo-PNkM

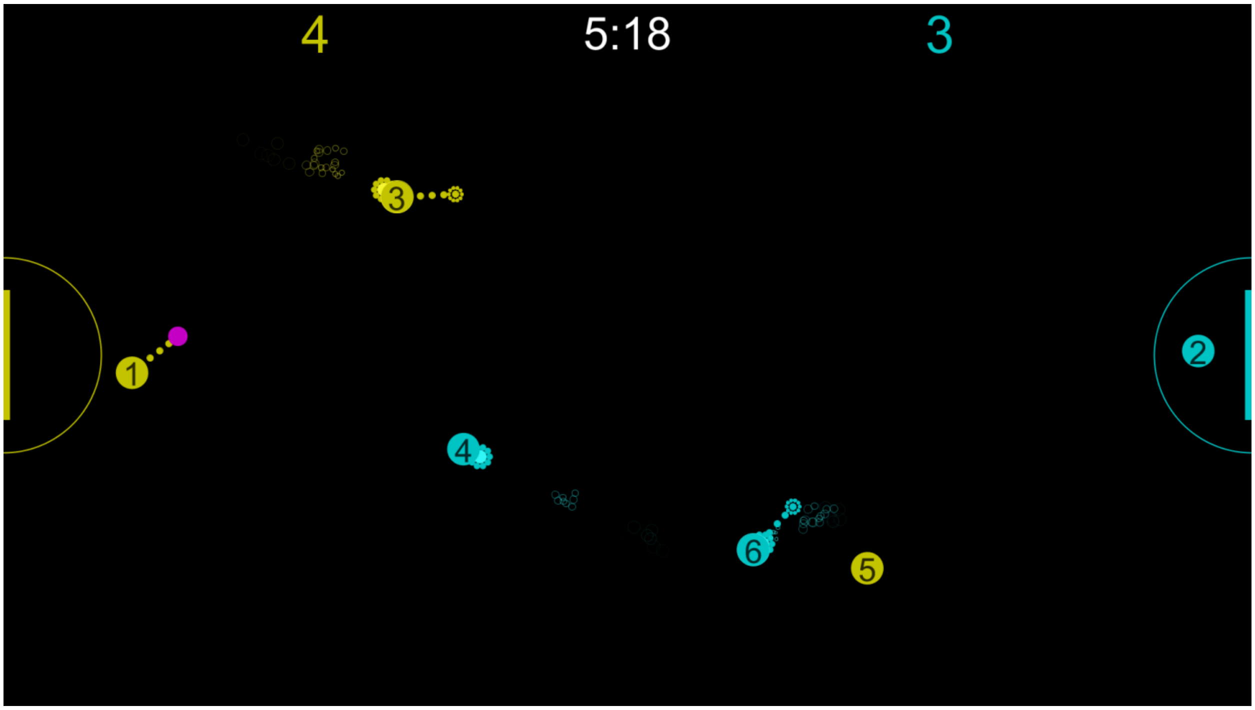
CHI 2015 Video Figure: https://www.youtube.com/watch?v=T9VSnvkjGPc

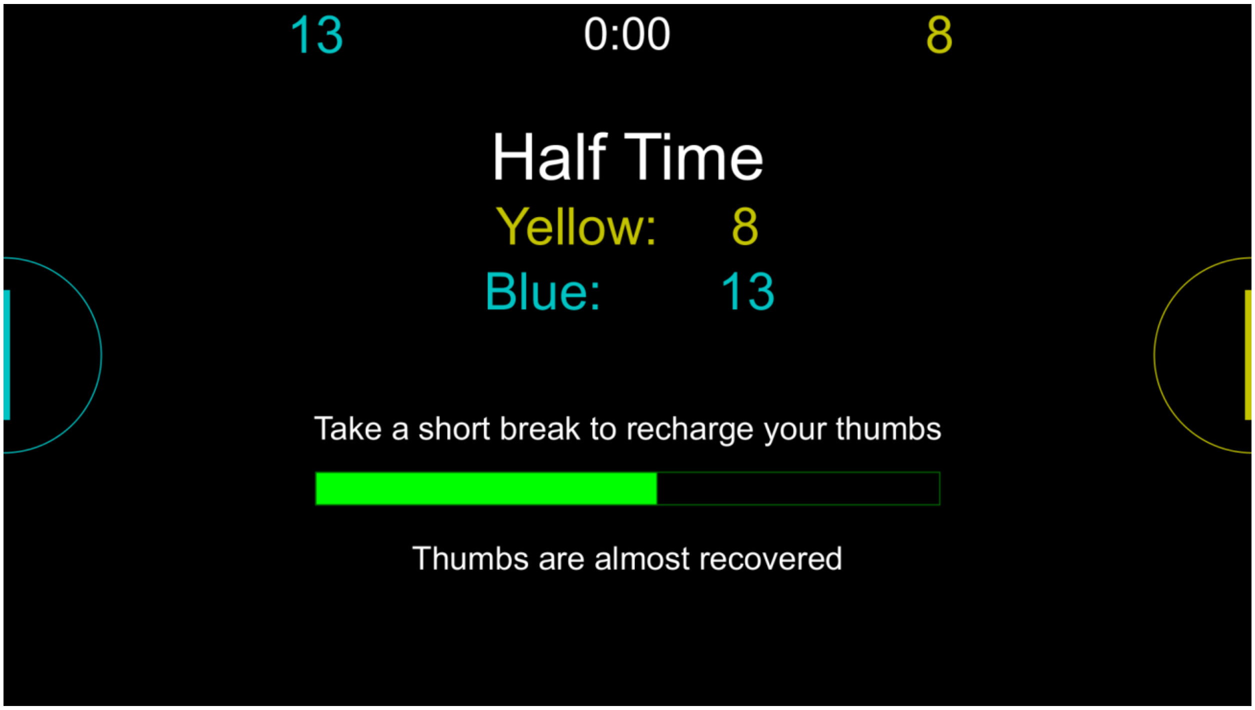
Jelly Polo IGF Submission Video: https://www.youtube.com/watch?v=D_lQyCjRlQU

E.2 Current Version Screenshots

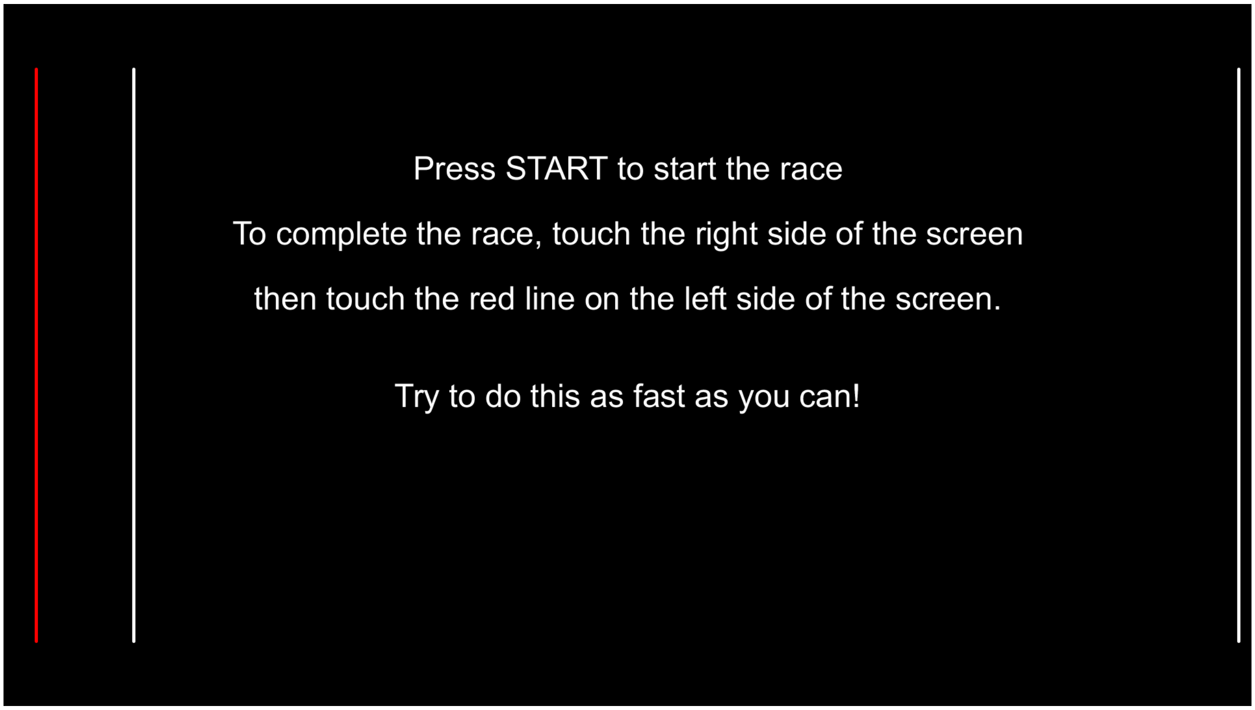


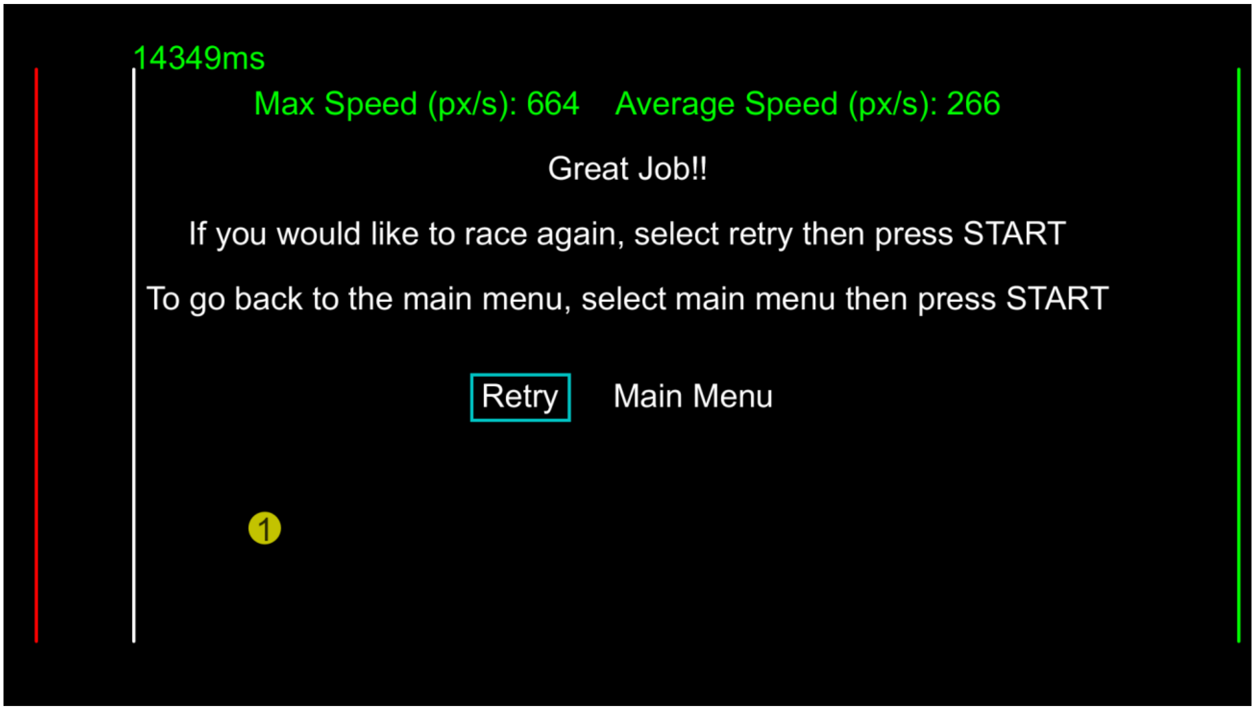


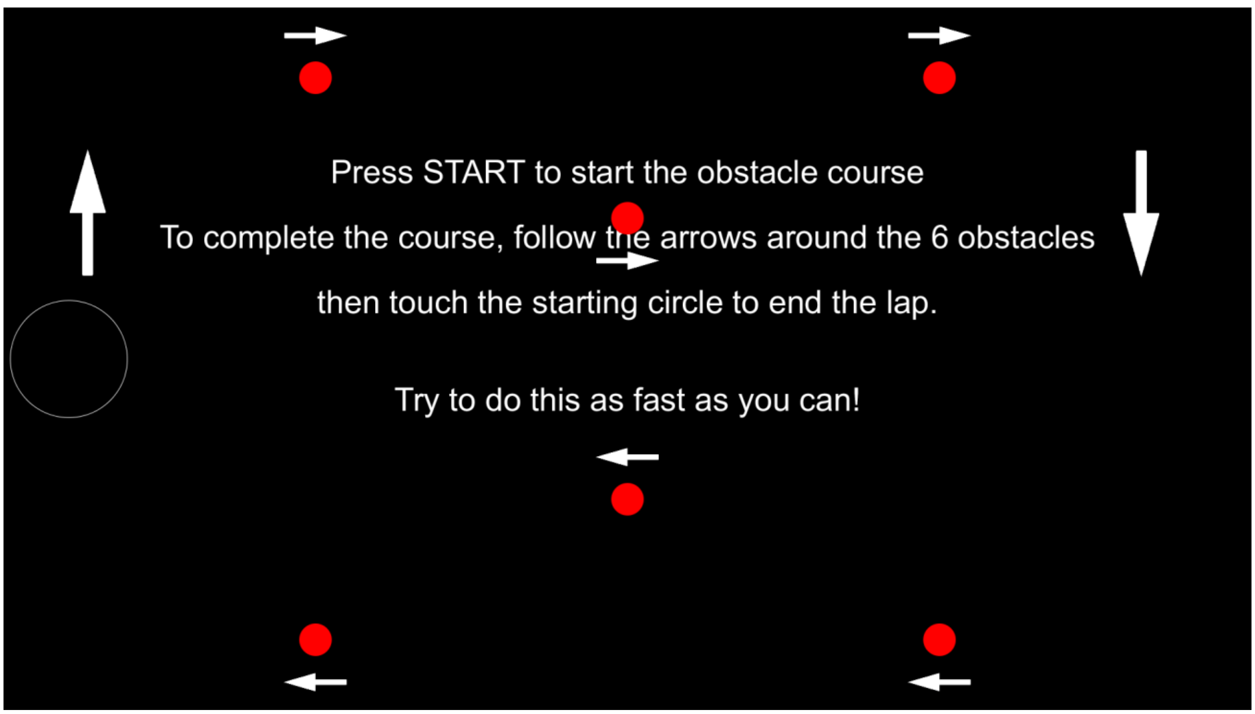

4
5:18
3
3
1
2
4
6
5

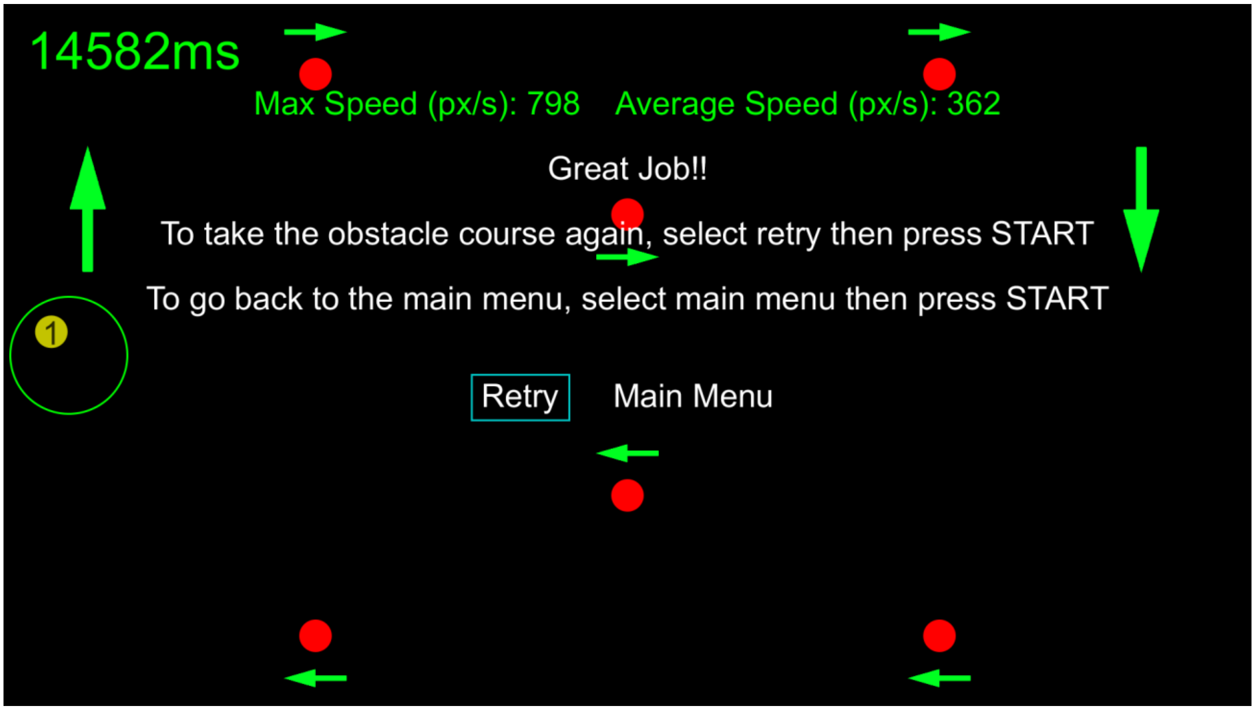

13
0:00
8
Half Time
Yellow: 8
Blue: 13
Take a short break to recharge your thumbs
Thumbs are almost recovered

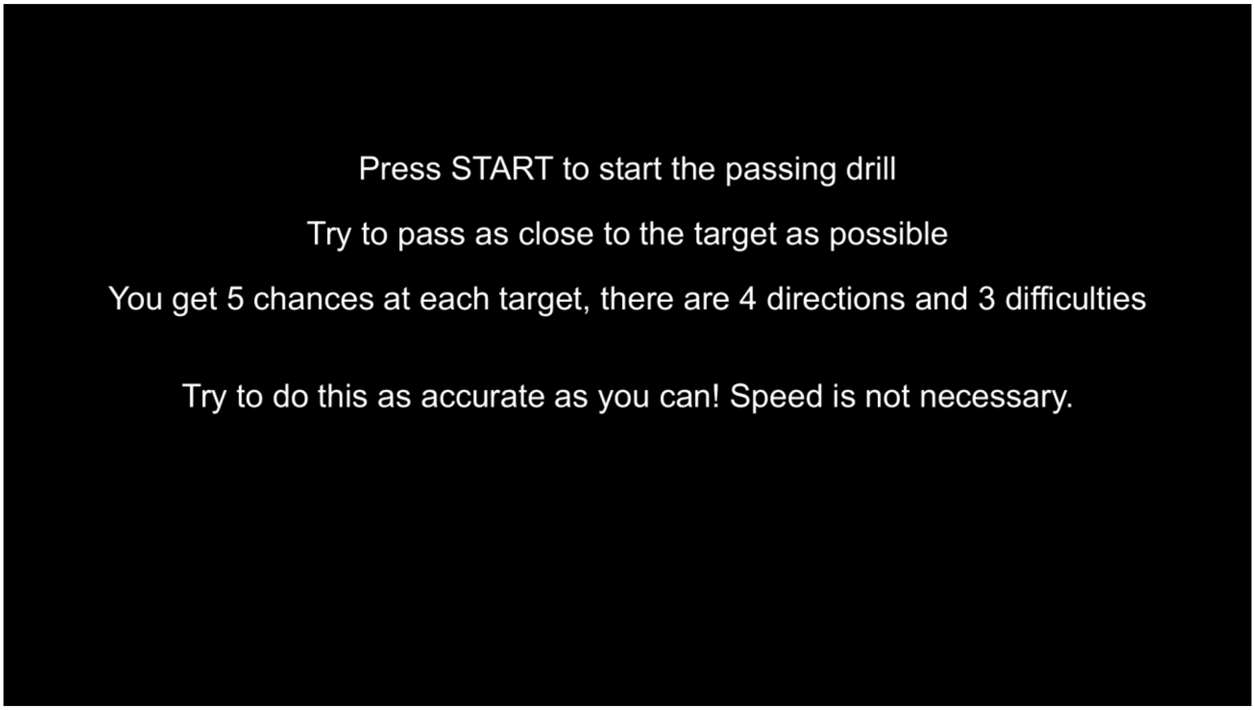

Game Over
Yellow: 20
Blue: 18
Yellow Wins!!
Press Start to go back to title screen

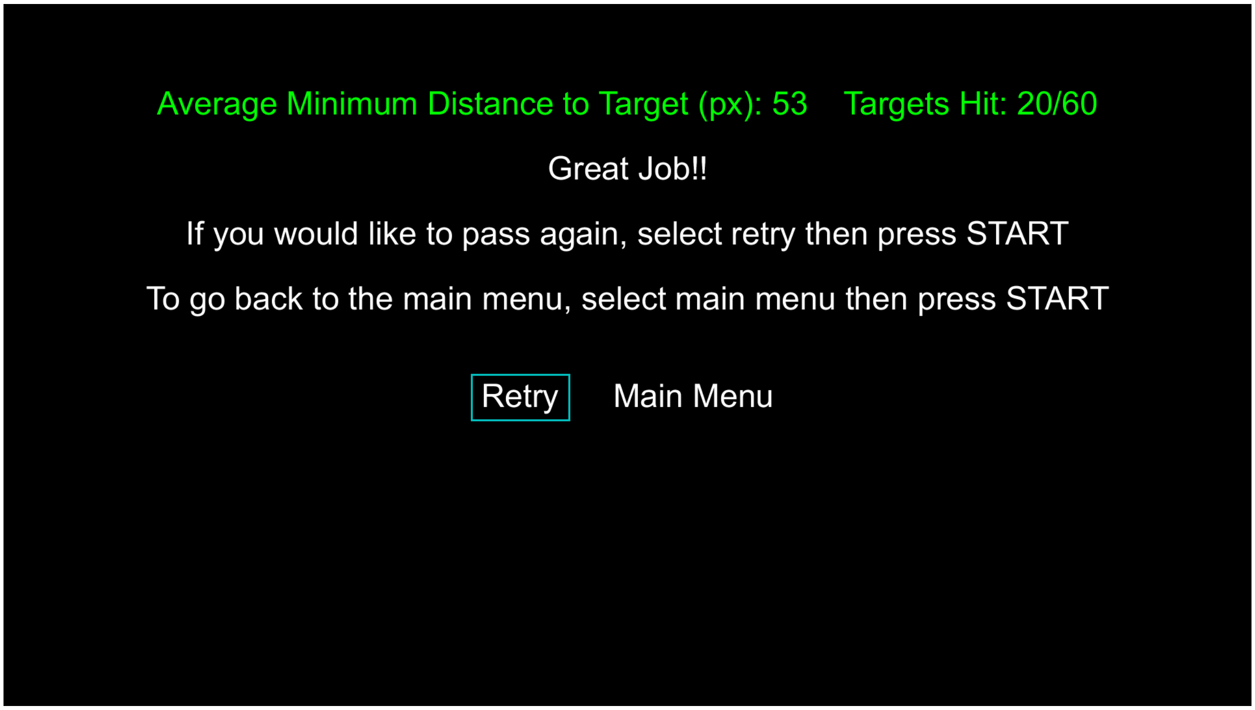

Press START to start the race
To complete the race, touch the right side of the screen
then touch the red line on the left side of the screen.
Try to do this as fast as you can!


14349ms
Max Speed (px/s): 664
Average Speed (px/s): 266
Great Job!!
If you would like to race again, select retry then press START
To go back to the main menu, select main menu then press START
Retry
Main Menu
1


Press START to start the obstacle course
To complete the course, follow the arrows around the 6 obstacles
then touch the starting circle to end the lap.
Try to do this as fast as you can!


14582ms
Max Speed (px/s): 798
Average Speed (px/s): 362
Great Job!!
To take the obstacle course again, select retry then press START
To go back to the main menu, select main menu then press START
1
Retry
Main Menu


Press START to start the passing drill
Try to pass as close to the target as possible
You get 5 chances at each target, there are 4 directions and 3 difficulties
Try to do this as accurate as you can! Speed is not necessary.


Average Minimum Distance to Target (px): 53
Targets Hit: 20/60
Great Job!!
If you would like to pass again, select retry then press START
To go back to the main menu, select main menu then press START
Retry
Main Menu