BOOTLE RUMBLE: GAMIFYING REHABILITATION EXERCISE FOR YOUTH WITH CEREBRAL PALSY

by

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Abstract

Youth with cerebral palsy (CP) may be prescribed rehabilitation exercises by physiotherapists in order to improve or maintain motor function as they grow into adolescence. However, in the field of physiotherapeutic medicine, adherence to exercise prescriptions has been shown to be low. Motivation and enjoyment have been identified as important factors of adherence to prescribed exercise, and gamification of rehabilitation exercise has been shown in some cases to improve motivation, enjoyment, and exercise adherence for youth with cerebral palsy. In this thesis, we present Bootle Rumble, an exercise video game for youth with cerebral palsy which intends to motivate high-quality rehabilitation exercise without sacrificing enjoyable gameplay.

Bootle Rumble’s design balances four distinct constraints: (1) it must motivate high-quality exercise; (2) it must be balanced for effort rather than individual ability; (3) it must be accessible to youth with CP; and (4) it must be fun. These constraints led to several unique game design decisions, which we describe in this thesis.

To gain early evaluation of the design decisions that underly Bootle Rumble, we conducted a pilot study involving three participating youth with CP, their parent/guardians, and a participating physiotherapy assistant (PTA) who works with youth with CP. This pilot study focused on evaluating (1) our form-tracking mechanic, in which players’ quality of exercise influences the outcomes of in-game choices, (2) player enjoyment while playing Bootle Rumble, and (3) the effectiveness of Bootle Rumble’s design.

The results gathered from our pilot study show promise for Bootle Rumble as an enjoyable adjunct to rehabilitative exercise for youth with CP. Our PTA’s observations suggest that Bootle Rumble incentivizes high-quality exercise. Responses from our participating youth with CP suggest that Bootle Rumble is enjoyable. We further leverage our results to evaluate several of Bootle Rumble’s design decisions. These design decisions may be useful to future developers intending to gamify rehabilitation for youth with CP and other motor disorders.
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I want to extend my sincerest gratitude to Dr. Nicholas Graham for teaching me the art of game development, introducing me to the science of serious games, and guiding me through my graduate studies. He has been nothing but supportive and free of judgement throughout my time at Queen’s University. I also want to thank my colleagues at the EQUIS Lab for always being friendly and cooperative.

A wise person once told me that life is about balance. With that in mind, I want to thank my family for encouraging my work, and my friends for distracting me from it.
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<th>Description</th>
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<tr>
<td>CP</td>
<td>Cerebral Palsy</td>
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<tr>
<td>GMFCS</td>
<td>Gross Motor Function Classification Scale</td>
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<tr>
<td>MACS</td>
<td>Manual Ability Classification Scale</td>
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<tr>
<td>PT</td>
<td>Physiotherapist</td>
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<td>PTA</td>
<td>Physiotherapy Assistant</td>
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Chapter 1

Introduction

Exercise games, or exergames, are digital games which integrate physical activity into gameplay. Adherence is the willingness of a person to starting and continuing a treatment program, such as a prescribed exercise regimen [6,45]. In the field of rehabilitation medicine, adherence to rehabilitation exercise prescriptions has been shown to be low, with as few as one third of clients adhering to their prescription [43]. Improving adherence is valuable for the specific population of youth with cerebral palsy (CP), for whom rehabilitation exercise may be prescribed [29]. Jannink et al. developed an exergame which was shown to improve motivation [17] for youth with cerebral palsy to perform rehabilitation exercise. Bryanton et al. developed an exergame which improved exercise adherence [3] for youth with cerebral palsy. In this thesis, we present an exergame called Bootle Rumble which intends to motivate high-quality rehabilitation exercise for youth with CP. A key feature of Bootle Rumble is form-tracking, in which players’ quality of exercise during play influences the effectiveness of in-game actions.

The design of Bootle Rumble balances four design constraints: incentivizing high-quality exercise, balancing for effort rather than ability, ensuring accessibility for youth with CP, and ensuring fun gameplay. These constraints led to several design decisions, which we describe in this thesis.

We ran a pilot study with three youth with CP, their parent/guardians, and a participating physiotherapy assistant (PTA) to assess (1) the effect that the form-tracking mechanic has on quality of exercise while playing Bootle Rumble, (2) players’ general enjoyment while playing Bootle Rumble, and (3) the effectiveness of the design decisions that underly Bootle Rumble. Participants reported positive experiences while playing Bootle Rumble. High quality of exercise was observed by a participating physiotherapy assistant (PTA). Furthermore, the PTA observed
higher quality of exercise when the form-tracking mechanic was enabled. However, the PTA’s qualitative observations were not corroborated by the quantitative “form scores” that she reported during play. Further research is required to determine the importance of the form-scoring mechanic with regards to quality of exercise while playing Bootle Rumble.

1.1 Problem

Cerebral Palsy (CP) is a group of movement disorders characterized by reduced motor function caused by abnormal brain development during pregnancy or early childhood [40]. Though CP is a non-progressive disorder [40], people with CP often experience a decline in motor function as their bodies develop into adulthood [15]. To prevent this decline, youth with CP may perform rehabilitation exercises prescribed by a physiotherapist [29]. These rehabilitation exercises may be completed in a clinical setting, but in-clinic rehabilitation can be costly to provide, and not all children with CP can be adequately treated in this way [45]. A potential solution to this problem is the prescription of at-home rehabilitation exercise for youth with CP.

However, adherence to rehabilitation programs has been shown to be low in various populations, to the extent that up to two thirds of clients may not be adherent to their treatment programs [43]. Motivation [42,45] and enjoyment [42] have been identified as factors which influence adherence to exercise programs. The gamification of rehabilitation has been shown in some cases to increase clients’ motivation [17] and exercise compliance [3] in youth with CP. This suggests that gamifying rehabilitation exercise for youth with CP could be a promising approach for improving adherence to prescribed rehabilitation exercises.

Various sets of guidelines exist for the design of (a) compelling exercise games [23,25] and (b) accessible games for individuals with reduced cognitive/motor/sensory abilities [11]. These sets of guidelines are congruent in some ways and contradictory in others. Hernandez et al. attempted to balance these two sources of guidelines to produce a set of guidelines for action-based exercise games for youth with CP. As an example, they provide Liberi, which gamifies
cardiovascular exercise using an exercise bicycle [16]. The design of a game which motivates repetitive rehabilitation exercises presents different constraints. Firstly, such a game would have to be designed to incentivize high-quality exercise. Secondly, such a game would need to support different rehabilitation exercises, which may vary greatly in form and function.

1.2 Solution

We designed and implemented Bootle Rumble, a game intended specifically to motivate high-quality rehabilitation exercise for youth with CP. Bootle Rumble is a two-player competitive strategy game in which players take turns making strategic choices and performing exercises. Each turn of Bootle Rumble is divided into two phases: (1) the strategy phase, in which players are free to make strategic choices, and (2) the rumble phase, where players perform exercises from an individualized exercise regimen. During the rumble phase, the quality of the player’s exercise is graded by a human observer, on a per-repetition basis, on a scale of one to three. These grades, called form scores, in turn influence the effectiveness of the player’s strategic choices. This real-time feedback mechanic, called form-tracking, is the primary method that Bootle Rumble employs to motivate high-quality exercise for youth with CP.

Beyond the form-tracking mechanic, the design of Bootle Rumble balances four separate design constraints: (1) the game must motivate high-quality exercise, (2) it must be accessible for youth with CP, (3) it must be balanced for effort rather than the ability levels of the players, and (4) it must be fun. Each one of these constraints resulted in several design decisions, which we describe in this thesis.

1.3 Evaluation

We devised and executed a pilot study to obtain early evaluation of Bootle Rumble and its game mechanics, with a focus on the form-tracking mechanic. We aimed to explore three primary research questions: (RQ1) Does the presence of the form-tracking mechanic in Bootle Rumble improve players’ quality of exercise? (RQ2) Do participants enjoy playing Bootle
Rumble? (RQ3) How effective are Bootle Rumble’s design decisions with respect to quality of exercise, accessibility, game balance, and fun?

Our pilot study involved three youths with CP who played Bootle Rumble, their parent/guardians, and a participating physiotherapy assistant (PTA), who assisted in simulating the form-tracking mechanic by providing real time feedback on players’ quality of exercise. We gathered data about quality of exercise, exertion, and enjoyment during play, and conducted semi-structured interviews to learn more about the state of rehabilitation for youth with CP, and the effectiveness of specific mechanics present in Bootle Rumble. The results of this pilot study are promising overall. Players generally had positive experiences playing Bootle Rumble, and our participating PTA observed an improvement in quality of exercise when the form-tracking mechanic was enabled. However, further research is required to quantitatively assess the effectiveness of the form-tracking mechanic at incentivizing high-quality exercise during play.

1.4 Contributions
This thesis contains the following contributions:

- **Bootle Rumble, a rehabilitative exergame for youth with cerebral palsy:** We provide a prototype exergame, titled Bootle Rumble, which intends to motivate high-quality at-home rehabilitation exercise for youth with cerebral palsy.

- **Summary of design decisions for Bootle Rumble:** We enumerate Bootle Rumble’s design decisions, which themselves arose from four separate design constraints: (1) motivating high-quality exercise, (2) balancing for effort rather than ability, (3) aiding accessibility for youth with cerebral palsy, and (4) ensuring fun gameplay.

- **Evaluation of Bootle Rumble’s design decisions:** We assess the effectiveness of our design decisions for Bootle Rumble via feedback gathered from a pilot study with three youths with cerebral palsy, with a focus on the form-tracking mechanic.
Discussion of the domain of rehabilitation for youth with cerebral palsy: Based on interview responses, we report information about attitudes towards rehabilitation for youth with cerebral palsy from the perspective of their parent/guardians and a physiotherapy assistant (PTA) who works with youth with cerebral palsy.

The exergame at the forefront of this thesis, Bootle Rumble, has core game mechanics based on those present in Brains & Brawn, a strength training game for typically-developing people [37,38]. In Brains & Brawn, gameplay is divided into two distinct phases: the strategy phase, and the exercise phase. These phases are separate but affect each other meaningfully. This allows a player to have freedom of choice without risking the integrity of their exercise regimen.

This thesis was made possible by several contributors at Holland Bloorview Kids Rehabilitation Hospital. These contributors were integral to the initial design of Bootle Rumble, the recruitment of participants for our pilot study, and the completion of study sessions. They are: Dr. Elaine Biddiss, Maritza Basaran, Ajmal Khan, Dr. Hamilton Hernandez, Marcela Correa, and Alexander Hodge. The art assets for the eponymous Bootle characters present in Bootle Rumble were originally designed by a team of faculty and students from Centennial College for use by the Holland Bloorview Kids Rehabilitation Hospital. They are: Alexey Berezov, Michelle Lee, Yurii Shremov, and Matt Soucy.

The structure of this thesis is as follows: in Chapter 2, we synthesize relevant literature to understand the domain of rehabilitation for youth with cerebral palsy, guidelines for the design of exergames and accessible games, examples of exergames utilizing bodily input, and examples of systems which provide automated feedback on quality of exercise. In Chapter 3, we introduce Bootle Rumble, a rehabilitative exergame for youth with cerebral palsy, and enumerate our design decisions for Bootle Rumble. In Chapter 4, we summarize our pilot study which intended to evaluate Bootle Rumble and its mechanics, with a focus on the form-tracking mechanic. In Chapter 5, we provide the results gathered from the pilot study. In Chapter 6, we use those results
to draw tentative conclusions about the effectiveness of Bootle Rumble at achieving its intention.

In Chapter 7, we summarize our work and discuss potential avenues for future work.
Chapter 2

Literature Review

In this chapter, we review scientific literature relevant to the design of rehabilitation exercise games for youth with cerebral palsy. The first step in gamification is to understand the problem domain. Therefore, we examine rehabilitation for youth with cerebral palsy in general. We then identify existing guidelines for gamification of that domain. What makes a compelling exercise game? How do we ensure the game is accessible? Do the answers to these questions have shared qualities, or do they contradict each other? After synthesizing the existing guidelines, we consider how they are applied in games which make use of bodily input. Next, if we intend to provide feedback on quality of exercise to the user, we must examine approaches to automated movement feedback. Finally, we consider examples of exercise games which make use of movement feedback, and how they relate to existing game design guidelines.

We present this literature review in five subsections: in section 2.1, we discuss cerebral palsy in general, forms of treatment for youth with CP, and the challenge of increasing adherence to those treatments; in section 2.2 we synthesize guidelines for the design of accessible games, exercise/rehabilitation games for typically-developing people, and exercise/rehabilitation games for youth with CP; in section 2.3 we review motion tracking in exercise games and rehabilitation games; in section 2.4 we discuss papers related to movement tracking and automated form feedback via motion capture technology such as the Microsoft Kinect [24]; in section 2.5 we discuss examples of automated and manual movement feedback in exercise/rehabilitation games.

2.1 Cerebral Palsy and Rehabilitation

Cerebral Palsy (CP) is defined as “a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain” [40]. The impact of CP on
motor function is classified using the Gross Motor Function Classification Scale (GMFCS) and the Manual Ability Classification Scale (MACS). Both are divided into five levels, increasing with severity of impairment [1,10,30]. The GMFCS describes people’s gross motor function: for example, at GMFCS level III, a person with CP walks using a handheld mobility device or uses a wheeled mobility device when traveling longer distances [30]. The MACS describes people’s ability to handle objects in everyday activities: at MACS level III, a person with CP “handles objects with difficulty”, and “needs help to prepare and/or modify activities” [1,10].

Though CP is a non-progressive disorder [40], youth with CP may experience declining motor function as they grow through adolescence [15]. For some, this means transitioning from walking without aid to using a walker, or from a walker to a wheelchair. To reduce this decline in motor function and increase range of movement and mobility, youth with CP may attend regular physiotherapy sessions, where a physiotherapist prescribes and administers an exercise regimen consisting of varying forms of rehabilitation exercise [29]. Both strength and aerobic exercise have been shown to have “significant benefits that improve the quality of life of … patients” [35]. Strength training programs have been shown to improve muscle strength in youth and adults with CP, without presenting any detrimental effects [9]. There is some evidence that exercise routines focusing on lower-limb strength (and cardiovascular fitness) are beneficial for youth with CP [47]. For upper extremities, “child-friendly” constraint-induced therapy—therapy in which the use of non-targeted limbs is restricted to focus on use of the target limb—can improve the frequency and quality of use and movement of the extremity [5]. These examples all point towards some form of repeated exercise as being of benefit to youth (and adults) with CP.

Many rehabilitation exercise programs require supervision from a physiotherapist. The costs, time, and resources required for supervised exercise programs are high, to the point that not all children with CP can receive the amount of rehabilitation they need in this way [45]. This points to home-based rehabilitation as an option to reduce the resources required to perform...
regular rehabilitation exercise. However, many problems arise when implementing home-based rehabilitation programs.

Adherence is the commitment that a client has to starting and continuing a treatment program, such as attending in-clinic therapy sessions and performing home-based therapy [6,45]. Improving adherence has already been identified as a problem, as it has been listed on the Revised Research Agenda for Physical Therapy [13]. While exact rates of adherence for youth with CP are not known, most studies of physiotherapeutic treatment programs for other populations show that one to two thirds of clients are not adherent to prescribed exercise [43]. In general, rehabilitation exercise adherence is more associated with enjoyment of exercise and social interaction than it is to fitness or appearance [42]. Motivation has been shown to be an important factor in adherence as well [45]. In specific cases, the gamification of rehabilitation has been shown to have potential to improve motivation [17] and exercise adherence [3] for kids with CP. However, there are many challenges presented in designing a compelling, accessible, exercise game for the specific population of youth with CP.

2.2 Guidelines for Accessible Rehabilitation Games

Various sets of guidelines have been published as resources for designers of exercise games for typically-developing people [23,25], accessible games for people with cognitive/motor/sensory disabilities [11], and exercise games for youth with CP specifically [16]. We will first examine guidelines for accessible games in general, followed by guidelines for exercise games for typically-developing people. Then we will examine guidelines for exercise games for youth with CP, and highlight similarities between the three groups.

2.2.1 Guidelines for Exercise Games

Mandryk et al. provide a series of guidelines for designing exercise games in “Designing Games to Discourage Sedentary Behaviour”, which they generated through examination of various sources. These guidelines are as follows:
1. “Providing an easy entry into play” [23]. The authors mention that there are many barriers which may prevent people from exercising regularly. People must find time in their schedules to exercise, which includes the “start-up and recovery” times. There may be “physical barriers” such as seasonal weather which prevents people from exercising. The authors suggest that minimizing these barriers when designing an exergame will cause people to play more frequently [23].

2. “Implementing achievable short-term challenges to foster long-term motivation” [23]. The authors reference Yim and Graham’s paper in which they state that “attaining short-term success … breaks up long-term goals into manageable steps” [50]. preventing people from becoming discouraged. Implementing this strategy in an exergame will keep people playing long-term [23,50].

3. “Providing users with appropriate feedback on their exercise effort” [23]. To give players some understanding of their exercise performance, the authors suggest providing exercise feedback. This feedback can be provided through “progress charts” after gameplay, or in real time. In multiplayer environments, the authors suggest obfuscating the players’ fitness levels “to avoid direct competition between players” [23].

4. “Implementing individual skill-matching to keep players engaged” [23]. The challenge of an exergame will not be the same for each individual player due to variance in fitness/ability levels. The authors point out that exergames should be balanced to account for this difference by scaling the challenge to the individual’s ability level, especially in a multiplayer setting. They reference Stach et al. who said that games should be balanced by “driving play mechanics by a player’s exertion relative to their own fitness level (e.g. through percent of target heart rate), rather than through absolute metrics of effort (e.g. through cycling revolutions per minute)” [23,44].
5. “Supporting social play to foster interaction and increase exercise motivation” [23]. The authors claim that social interaction is a “core component” of exercise motivation. They mention the insights of Mueller et al. who state that social bonding can be generated via “meta-gaming (game-related activity that occurs outside of actual gameplay)” [23,25], which further increases players’ motivation.

2.2.2 Guidelines for Accessible Games

GameAccessibilityGuidelines.com, henceforth referred to as GAG, provides a resource for game designers to create games—though not necessarily exercise games—which are accessible to people with sensory, cognitive, and/or motor disabilities. The authors also separate their considerations for each type of disability into 3 groups: (1) basic considerations which have a broad scope and are easy to implement, (2) intermediate considerations which require more planning and effort to incorporate, and (3) advanced considerations for “profound impairments” [11]. Youth with CP experience motor disability, and are also more likely to have difficulty with visual perception [21], which is a cognitive impairment. Therefore, we focus on the considerations the authors outline for users with cognitive and motor disabilities:

1. Consider the accessibility of the control scheme and the complexity of game input required to play: Allow controls to be configured; Utilize a simple control scheme, or offer an optional, simpler, control scheme; support different input devices; ensure that any game interactions which involve “complex inputs” (such as gesture or speech) can also be completed using simpler input methods (such as a control pad and button presses) [11].

2. “Do not make precise timing essential to gameplay”; Do not require repeated inputs, referred to as “button-mashing”, and do not require buttons to be held down; Avoid interactions that require concurrent inputs, such as a click-and-drag [11].
3. Support essential information with visuals/speech/text depending on the needs of the specific population, and indicate the current objectives/controls/interactive elements during gameplay [11].

2.2.3 Guidelines for Exergames for Youth with CP

In “Designing Action-based Exergames for Children with Cerebral Palsy”, Hernandez et al. outline a series of design considerations for the design of action-based exergames for youth with CP. They note that “traditional guidelines” for accessible game design can lead to “slow-paced games that are accessible to people with motor disabilities, but may lack the fun of action-based games” [16]. The authors’ revised set of guidelines relaxes these traditional guidelines to support action-oriented gameplay.

1. “Simplify level geometry” [16]. The authors recommend simple level geometry as a way to reduce the difficulty of inputs required to navigate the game world [16]. This guideline is similar to recommendations found on GAG, such as avoiding precisely-timed input, holding down buttons, or requiring multiple simultaneous inputs [11].

2. “Simplify level flow” [16]. The authors cite an accessibility recommendation presented by Grammenos et al. to avoid fast-paced gameplay [14,16]. In making an action-based game, Hernandez et al. found that they could include fast-based gameplay by simplifying level flow, which reduces the number of choices players have at any given time, and limits visual-spatial reasoning requirements [16].

3. “Reduce consequences of errors” [16]. This guideline is again in reference to considerations presented by GAG regarding simplified input [11]. Hernandez et al. state that gameplay can include some complex input requirements, but failing to provide those inputs should carry minimal penalties, to prevent players becoming frustrated [16].

4. “Limit available actions”. The authors claim that minimizing the number of possible actions during gameplay allows a simpler control scheme, and reduces the amount of
decisions players need to make [16]. This echoes the recommendation by GAG to use a simple control scheme [11]. In their game, Hernandez et al. keep gameplay interesting by making one button context-sensitive, allowing the user to access multiple actions with a single button, allowing more complex gameplay without increasing the number of available actions or complicating the control scheme [16].

5. “Remove the need for precise positioning and aiming” [16]. This guideline extends the guidelines presented by GAG which recommend avoiding precisely-timed or complex inputs [11]. The authors state that minimizing the need for accurate aiming reduces manual ability requirements for play [16].

6. “Make the game state visible” [16]. The authors state that by showing the player the game state explicitly, they reduce the need for players to use “visual spatial reasoning to deduce game state” [16]. This follows the guideline presented in GAG which states to reinforce essential information with visuals, sound and/or text depending on context [11].

7. “Balance for effort” [16]. This is similar to a guideline presented by Mandryk et al., which recommends balancing based on players’ fitness levels in order to maintain engaging gameplay [23]. In the context of the population of youth with CP, this allows players to fairly compete in-game regardless of their individual motor skills as described by the GMFCS and MACS [16].

In this section, we have discussed and synthesized existing guidelines for the design of (a) exercise games for typically-developing people, (b) accessible games in general, and (c) accessible exercise games for youth with cerebral palsy. Having examined these guidelines, we move on to examine games which utilize bodily input and discuss how they apply those guidelines.
2.3 Games with Bodily Input

A challenge in the design of exercise games is effectively linking a physical activity to a primary game mechanic. One may imagine playing a traditional game of Super Mario Odyssey [28], modified so that every two minutes, the player is asked to pause the game and do 15 jumping jacks; in this hypothetical example, the exercise is completely disconnected from the gameplay. In this subsection, we consider exercise/rehabilitation games which utilize motion tracking [26] as a primary game mechanic. These games aim to increase motivation for clients to perform exercises, without sacrificing the benefits of the exercise or the quality of gameplay.

Within this subsection, we further separate exercise/rehabilitation games into two categories: general movement games, and specific movement games. We classify general movement games as exercise/rehab games which incentivize players to move their bodies, without requiring specific movements. Alternatively, we classify specific movement games as exercise/rehabilitation games which incentivize a specific movement. For example, we classify the game Dance Dance Revolution [20] as a general movement game since it requires players to dance, but does not incentivize one specific movement over others. Conversely, the game Wii Sports Tennis [27] would be classified as a specific movement game as it incentivizes players to swing their dominant arm in a specific way, without requiring the player to move any other part of their body.

Ni et al. presented two virtual games intended to balance therapeutic relevance and user experience for youth with CP (i.e. creating exercise games that are both fun and beneficial). Both games use the Kinect [24] to gather motion data, which is leveraged to create a core game mechanic for each game. The games were developed through an iterative design process using the input of youth with CP and their therapists [26].
The first game, “Dodgewall” (Figure 2-1), is intended to gamify lower limb movements, but can be classified as a general movement game because it requires full bodily movement. In “Dodgewall”, players position their bodies to fit through holes in a virtual “wall”. The game, inspired by the Japanese gameshow “Hole in the Wall”, was originally created for typically-developing users but was modified to maximize therapeutic relevance for youth with CP: the game allowed users to configure the number of walls per round, the speed of the walls, the leniency of the system with regards to success, and parameters surrounding wall openings. Depending on the system’s configuration, openings could (a) focus on “standing balance, trunk rotation, and sit-to-stand movements”, (b) require the user to move left or right to practice walking balance, or (c) require difficult stances for greater challenge [26]. This configurability allows the game to compensate for the specific needs of each individual player – a guideline highlighted in section 2.2 [16,23,44]. The game also provides rudimentary performance feedback, if only on a pass/fail basis, which satisfies another guideline from 2.2 [23].

Figure 2-1 A screenshot of Dodgewall [26]. The top left shows a silhouette of the player positioning their body to fit through a hole in the virtual wall, pictured in the center.
The second game, “Reach+” (Figure 2-2), is focused on upper limb motions, and is classified as a specific movement game. Inspired by games like “Neopets” [33], players must “reach for and grab food items from various points on the game screen and give them to their pet, scoring points in the process” [26]. Like “Dodgewall”, “Reach+” can be configured to maximize therapeutic relevance on an individual player basis. Depending on the settings, the game could (a) require players to extend their elbow to a certain degree to trigger an action in-game, (b) require players to use their right or left arm, or both, (c) require players to hold their position for some seconds when grabbing an item, and (d) place the pet’s “bowl” at a certain height on-screen to require more work, or to “elicit cross-body reach” [26]. Again, this configurability satisfies one of the guidelines in 2.2 [16,23,44]. The game also features six difficulty levels where objects move on-screen, actions are timed, or scoring options are modified [26].

The games were evaluated in 1.5-hour-long study sessions by (a) eight children aged 8-12 years and with CP of varying ability levels, and (b) six therapists, using custom and standardized questionnaires. Therapists answered custom Likert scale questions about their observations with regards to therapeutic relevance and the children’s ability to interact with the system. They also

Figure 2-2 A screenshot of Reach+ [26]. The player moves their arm to put the virtual treat—in this case, a fish—into the virtual pet’s bowl, scoring points.
completed the System Usability Scale (SUS) [2,26]. Children completed a custom survey regarding enjoyment and motivation, as well as the Physical Activity Enjoyment Scale (PACES) [18,26]. Therapists agreed that the participating children enjoyed and interacted effectively with both games, and disagreed that the movements required to play were too hard for the children to do. The average SUS score was in the 50th percentile when compared with data from over 5000 SUS responses [26]. The children themselves indicated a high enjoyment levels on both the PACES and the custom survey. The games’ ability to adjust difficulty settings and to focus on targeted goals was deemed highly valuable by the participating therapists [26]. However, each game was developed for a specific type of exercise; to motivate different types of exercises, entirely new games would need to be developed.

In this section, we have outlined some examples of exercise games which utilize bodily input to derive game mechanics for youth with CP. We have distinguished between general movement games and specific movement games: general movement games attempt to incentivize any form of movement for the player, while specific movement games attempt to incentivize some specific movement for the player to achieve a more specific therapeutic goal. We have seen that both general and specific movement games are valued by participating youth with CP for their enjoyability. We have also seen that configurability and adjustable difficulty is valued by participating therapists. With this understanding, we move towards a discussion of games which not only utilize bodily input, but provide real-time feedback on bodily movements. But, we must first understand the state of research in the field of automated movement feedback before discussing games which make use of such systems.

2.4 Movement Feedback Systems

In attempting to design a game which motivates high-quality at-home exercise, the question arises as to whether it is possible to algorithmically determine the quality of an individual’s exercise, without the presence of a human expert. In this subsection, we evaluate
several systems which intend to enhance rehabilitation exercise using motion tracking. These motion tracking systems are intended to provide real-time feedback for users with respect to their quality of exercise. One popular technology used in automated movement feedback systems is the Microsoft Kinect, a motion-sensing device capable of skeletal tracking and gesture recognition [24]. Every system evaluated in this subsection utilizes the Kinect for motion tracking; it has been identified as a low-cost solution which requires little calibration and no external sensors or marker balls [41], though it is less accurate than marker-based solutions such as the VICON [24,32,48]. The Kinect is no longer in production, but Kinect software is still supported by Microsoft [24]. Furthermore, several alternative consumer-level motion tracking devices exist which may fill Kinect’s role in the future [34].

Velloso et al. developed a system called MotionMA (Figure 2-3) which uses the Kinect [24] to compare the movement data of a user to that of a model demonstration [46]. The system records a demonstration movement, performed by a human expert, to generate a model of the movement. Using that model, the system is then able to examine the performance of future users.

![Figure 2-3 A series of screenshots from MotionMA [46]: the title screen (top left); the demonstration interface (top right); the feedback tweaking interface (bottom left); and the performance interface in which form feedback is provided (bottom right).](image)

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by comparing them to the demonstration movement in real time. The authors conducted a user study to determine if experts were able to formalize the elements of proper form for given movements, and found that they could not; in general, the users were not able to accurately estimate the angles they achieve in their own performance, nor were their performances completely alike. Thus, MotionMA does not require users to formalize the requirements for proper exercise; the system instead requires a demonstration of the exercise with which to compare future movements to determine their accuracy [46]. Velloso et al. evaluated the accuracy of MotionMA’s modelling approach to determine if the system could recognize strong and weak performance. The participants had mixed, but mostly positive, responses with regards to the system, its user interface, and its ability to provide feedback. The software was able to detect approximately 70% of mistakes in repeated movements [46]. This level of accuracy means that roughly 30% of movement errors were not caught by the system; greater accuracy would likely be required to track quality of exercise in a clinical, or rehabilitation, setting.

Acknowledging the high cost of rehabilitation sessions in a clinical setting, Zhao et al. describe a “rule-based system for rehabilitation exercise monitoring and guidance with realtime visual feedback”—the first of its kind—which uses the Kinect [24] to allow users to compare their form to that of a “coach” which demonstrates the optimal form for a given exercise (Figure 2-4) [51]. The system includes 4 separate use cases: (1) recording the movements of the demonstrator to be shown to the participant; (2) studying the movements of the demonstrator; (3) performing exercise with the system; (4) review of performance after an exercise session. Zhao et al. use two 3D avatars to display the movements of both the participant and a demonstrator on-screen for comparison. The system works by defining rules for a movement using an XML-based text file, and checking the movement data gathered from the participant via Kinect against those rules. It can then provide specific feedback to the user in real time as to their quality of exercise based on which rules were broken, and can send a user’s skeletal data (gathered by the Kinect) to
a physiotherapist for review. The authors claim that their approach is less computationally complex than other approaches such as MotionMA [46,51]. They also state that their system can provide more granular movement feedback than demonstration-based approaches by telling the user which XML rule they have broken. However, there is no discussion of the accuracy of the software [51]. Because of this, it is difficult to assess the validity of the rule-based approach to form feedback, nor compare it to the demonstration-based approach used by MotionMA.

Chang et al. presented a Kinect-based [24] system, called Kinerehab, intended to increase motivation for young adults with motor disabilities to perform rehabilitation exercises [4]. The system measures a user’s joint position to judge whether their movements have reached some “rehabilitation standard”, similar to the approach used by MotionMA [4,46]. Kinerehab also provides user feedback in the form of an animated whale who sings and flips his tail; “the more accurate the movement is, the more the flipping is and the louder the whale singing is” [4]. The
system includes a menu that therapists can use to adjust the rehab program. To test the Kinerehab system, Chang et al. ran a study with two participants with motor disorders, aged 16 and 17 years. Participants would take part in multiple sessions, in which they would perform multiple sets of 3 arm rehabilitation movements. They ran two sessions per day, divided into two phases: (1) a “baseline phase” in which a therapist would provide feedback on the participants’ quality of exercise but no assistive technology was used, and (2) an “intervention phase” where Kinerehab was used, but the therapist would provide no feedback [4]. Results showed that during baseline phases, both participants averaged under 50 “correct movements” per session; during intervention phases, that number increased to over 150 for both participants. The participants expressed interest in the system after the study, and “wanted to continue using it even after the experiment was completed,” but suggested that allowing two participants to use the system together could be beneficial to enjoyment [4]. This suggestion is reinforced by Hernandez’s guidelines outlined in chapter 2.2, in which the authors cite increased social isolation in youth with CP [16]. The therapist also stated that Kinerehab would “reduce her workload and improve the effectiveness of rehabilitation for students”. The therapist also suggested that the system include games to “enhance the entertainment provided by the system” [4].

In this subsection, we have analyzed the state of research in automated form-tracking and movement feedback. We have discussed two different approaches to form feedback: (1) demonstration-based approaches in which the user’s movements are compared to those of an expert demonstrator’s [4,46], and (2) a rule-based approach in which rules are defined for movements via XML [51]. We also examined a demonstration-based feedback system which takes the first steps toward gamification, in which users called for greater gamification in future work. In the following section, we will examine systems which attempt to leverage movement feedback to create interactive games.
2.5. Movement Feedback in Exercise/Rehab Games

While the games outlined in section 2.3 utilize motion tracking for their core game mechanics, there are yet more examples which utilize movement feedback, specifically. Motion feedback is a subset of motion tracking; motion feedback games require some form of motion tracking, but not all motion tracking games provide motion feedback. For example, Reach+ is aware that the player is performing movements, but does not provide feedback as to the quality of those movements [26]. In this subsection, we discuss examples of two movement feedback systems in exercise/rehabilitation games. One example makes use of an automated movement feedback system like those found in section 2.4 [41], while the other makes use of human expert knowledge to accomplish movement feedback [37,38].

Roy et al. discuss the application of a similar movement tracking/feedback system into a set of four “serious games” to enhance the effectiveness of rehabilitation for people with motor disabilities, using the Kinect [24] for movement tracking, in an application called Kinect-o-Therapy (Figure 2-5). A primary goal of Kinect-o-Therapy is to increase motivation for individuals to complete their rehabilitation program. Noting that individuals may feel “captive as a result of the wires and sensors attached to [their] body”, the authors opted to use the Microsoft

![Figure 2-5 Screenshots from Kinect-o-Therapy [41].](image)
Kinect [24] as a lightweight solution to motion tracking [41]. The minigames of Kinect-o-Therapy are based on exercises which youth with CP might perform in a typical rehabilitation session. In two of the four games included in Kinect-o-Therapy, the movement of the player is mapped to a 3D model on-screen. In one game, Shoulder Abduction, the 3D model demonstrates the correct and incorrect form for the target exercise before play begins. The game offers real-time feedback in the form of visual and auditory clues, and displays performance statistics at the end of each routine, with statistics from previous sessions for comparison. The games are also configurable to match the specific needs of patients on an individual basis. The authors did user testing with six categories of patients; they responded positively to the system, remarking that their exercise routines were more fun to perform with the system than without. They also did user testing of the backend configuration features with five specialists, who stated that the games would be beneficial to motivation in users with varying degrees of motor disabilities [41].

Richards and Graham developed a “repetitive motion exergame” for typically-developing people called Brains & Brawn (Figure 2-6), which attempted to afford meaningful player choices while maintaining the structure of exercise programs [37,38]. They define repetitive-motion exercises as exercises which “require the same movements to be performed over and over again in a precise manner” [38]. Brains & Brawn is a turn-based strategy card game in which players must perform repetitive motion exercise to play a card from their hand. Players draw from five separate decks of cards, each representing a character who specializes in certain attacks. The

Figure 2-6 Images of a person playing Brains & Brawn [37,38]. On the left, the player makes strategic choices. On the right, the player performs exercise.
player’s goal is to play cards from their hand which reduce the health points of the opponent’s characters, or replenish their own characters’ health points. Richards and Graham identify agency as an important element of video game play, and point out the challenges of providing agency in repetitive motion exergames: (1) repetitive motion exergames require the player to perform exercises with a “slow and controlled pace”, which cannot easily be mapped to any in-game action in the same way as cardiorespiratory exercises; (2) repetitive motion exergames must incentivize precise form while performing exercise, and disincentivize situations in which players choose not to focus on their form to “get the exercise out of the way”, (3) the potential rigidity of repetitive motion exercises leaves participants with very little agency around their choice of exercise, and a repetitive motion exergame must ensure that players perform their exact exercise prescription [38]. Richards and Graham were able to develop Brains & Brawn, a repetitive motion exergame which balances the constraints required to incentivize high quality exercise and the constraints required to make a compelling game. was accomplished by (1) providing strategic choices during times of rest between exercises, (2) applying the “illusion of agency” to exercise selection, and (3) incorporating quality of exercise as a game mechanic [38]. Richards’s design is also novel in that it is applicable to any repetitive motion exercise, and can therefore be used to gamify repetitive motion exercises in general.

To test the efficacy of Brains & Brawn, Richards and Graham ran a study with participants who were mostly unfamiliar with strength training exercise. Each session, a participant played Brains & Brawn until their exercise prescription was complete, at which point the game would end. Players were told that the game was automatically tracking their quality of exercise, but in reality, it was being tracked by a kinesiologist who provided feedback in real time. Participants then took part in a semi-structured interview and filled out Rhodes’ affective attitude questionnaire [36]. Richards and Graham found that: (1) players experienced agency
while playing Brains & Brawn; (2) players were incentivized to perform exercise with proper form; (3) players reacted positively to Brains & Brawn’s gameplay [38].

In this section, we have examined two examples of exercise games which track the quality of users’ bodily input and provide feedback to the user. Kinect-o-Therapy includes a minigame, Shoulder Abduction, which makes use of real-time automated movement feedback and provides performance statistics to be viewed after gameplay [41]. Brains & Brawn, a game for typically-developing adults, utilizes real-time movement feedback to incentivize higher-quality repetitive motion exercise, though the movement feedback is not automated, but provided by a human expert instead. In both cases, users responded positively to the movement feedback mechanics.

In this chapter, we have reviewed literature covering five topics, informing the design of rehabilitation exercise games for youth with CP, and highlighting the importance of the games themselves: (1) We outlined the current state of rehabilitation for youth with CP, the need for increased motivation and adherence for that rehabilitation, and the potential for gamification therein; (2) We summarized sets of design considerations for exercise games for typically-developing people, accessible games for people with visual/auditory/cognitive/motor disabilities, and exercise games for youth with CP specifically; (3) We examined a selection of games with bodily input, and identified design decisions which were valuable to players with CP and physiotherapists; (4) We discussed two distinct approaches to automated movement feedback, and their benefits and drawbacks; and (5) We evaluated some examples of exercise games which utilize movement feedback to incentivize high-quality rehabilitation exercise. Having synthesized literature from these five domains, we have gathered the information needed to design a game for kids with CP which incentivizes high-quality rehabilitation exercise, which will be discussed in the next chapter.
Chapter 3

Bootle Rumble: Designing for Fun, Accessibility, and Rehabilitation

Bootle Rumble was developed to study the effect of form-tracking on quality of exercise and enjoyment while playing rehabilitation exercise games. Bootle Rumble takes the form of a two-player strategic turn-based game. The gameplay is based on the game “Brains & Brawn” by Richards and Graham [37,38] (described in Chapter 2.5), which is itself loosely based on the combat seen in turn-based RPGs such as Pokémon FireRed (Figure 3-1) [12,49]. In Bootle Rumble, each player controls a team of four characters, called “Bootles”: the Knight, the Wizard, the Ninja, and the Doctor. Bootles are arranged in a 2x2 grid, in which tougher characters stand in the front row and weaker characters stand in the back row. Each character has a different number of health points, and a unique action which is useful for different situations: The Knight attacks with his sword to perform high damage on a single target, but can only attack an enemy in the front row; The Ninja does moderate damage to a single target in any row; The Wizard does low...
damage to several enemies; The Doctor can heal single allies. A screenshot of Bootle Rumble’s characters is shown in Figure 3-2.

The Bootles on a given player’s team are referred to in-game as friends, while the Bootles on their opponent’s team are referred to as foes. If a Bootle’s health points reach zero, the Bootle *flees* the battle, and returns in three turns. The winner of the game is determined by which player has caused the most foes to flee. Therefore, a player’s goal is to cause opposing Bootles to flee, while preventing their own Bootles from fleeing. The original concept art for the Bootles was provided by Holland Bloorview Kids Rehabilitation Hospital, and is used in several other of their experimental games for youth with CP.

Prior to gameplay, a *regimen* of exercises is defined for each player, which the game requires them to perform during gameplay. An exercise regimen consists of multiple *sets*, where each set represents some number of *repetitions* of an exercise. A player’s exercise regimen is chosen by a physiotherapist based on the player’s own abilities and therapeutic needs. Bootle

![Figure 3-2 A screenshot of Bootle Rumble during the strategy phase. Each player controls four characters: (1) The Wizard; (2) The Knight; (3) The Ninja; (4) The Doctor. Each character has a unique action, and a unique amount of health points.](image-url)
Rumble currently supports eight different exercises, which can be modified for different ability levels. Each exercise is supported via a short animation of a character named Botley performing the exercise, which is shown in-game as a reference for players as they exercise (Figure 3-3). The game is extensible to include more exercise animations, and the animations themselves require little development cost to create. Therefore, the game can support most repetitive exercises with limited development cost. One limitation to the generalizability of Bootle Rumble is that the player should be able to see the screen while they are performing exercise, so they are able to monitor their quality of their exercise, as well as the gameplay. Therefore, exercises which require the user to be prone, or which otherwise obstruct the game display, are not generally suited for gamification with Bootle Rumble.

During gameplay, each player takes turns making strategic choices and performing exercises. Each turn is comprised of two distinct phases: (1) the strategy phase, in which players choose a friend to perform an action and a target Bootle to act upon (either a friend or foe

![Figure 3-3 A screenshot of Bootle Rumble immediately prior to the rumble phase. During gameplay, a player has been prescribed a set of six hip abductions, and a character named Botley performs hip abductions as an example of proper form on the right side of the screen.](image)
depending on the action), and (2) the *rumble phase*, in which players are directed to perform exercise and the action they chose in the strategy phase is carried out.

A player’s turn begins with the strategy phase. During this phase players choose a friend, and a foe to attack (or a friend to heal if they have selected the Doctor). Depending on the game state, the player must make strategic choices. For example, if a player’s Bootle is at risk of running out of health points, they may choose to heal the Bootle using the Doctor; if an enemy’s Bootle is near zero health points, the player may choose to target it with the Ninja. An overview of the strategy phase is provided in Figure 3-4.

When the player has selected a friend to perform an action and a target to act upon, they are then presented with the *activity wheel*, which they spin to receive an exercise from their predefined set of exercises. Once the player has received an exercise, the game enters the rumble phase, in which the layout of the game changes by embedding a web-cam mirror so the player can

![Figure 3-4 An overview of the strategy phase of Bootle Rumble. It is Lion’s turn. (1) The player chooses a friend. In this case, they choose the knight. (2) The player chooses a target. In this case, they choose the wizard. (3) The player is presented with the activity wheel, which they spin. (4) The activity wheel presents a set of exercises to perform. In this case, the player must perform five calf flexes.](image-url)
watch themselves as they exercise (Figure 3-5). The player then performs the provided exercise, while an observer tracks their quality of exercise and inputs it into the game, as described below.

While the player exercises, their quality of exercise is measured on a scale of 1 to 3 per repetition. We call this measurement a *form score*. Form scores are provided by an observer during gameplay, on a per-repetition basis. This observer could be a physiotherapist, a family member, or a friend. The observer provides form scores based on rubrics that are defined prior to gameplay for each exercise in the players’ sets. Each time the observer provides a form score (i.e. immediately after each repetition performed by the player), the player’s selected ally performs their action on their chosen target. If the form-tracking mechanic is enabled, the player’s form score affects the quality of the allied character’s action. For example, a Knight’s attack does considerably more damage with a form score of 3 than 1. A chart displaying the attack and health point information for each Bootle is provided in Table 3-1.

The design of Bootle Rumble balances four sources of constraints: (1) the game must promote high quality exercise; (2) it should be balanced such that two players with different ability levels can play together (3) it should be playable and enjoyable for youth with CP; and (4)

![Figure 3-5 A screenshot of Bootle Rumble during the rumble phase. In the rumble phase the game’s layout changes to accommodate a webcam mirror.](image)
being a game, it should be fun. These constraints, and the design decisions that arose from them, are discussed in the following subsections.

### 3.1 Promoting High-Quality Exercise

Bootle Rumble intends to incentivize high-quality exercise by (1) providing feedback on the quality of players’ exercise based on form score using visual effects, voiceover audio, and strategic benefits, (2) displaying animations of the character Botley performing the same exercise as the player during the rumble phase, and (3) showing the player a webcam ‘mirror’ during the rumble phase. When designing exercise games, designers must be mindful of what kind of exercise they are trying to promote, and avoid incentivizing poor quality exercise or dangerous form. For example, one could design a game in which two players compete to see who can

<table>
<thead>
<tr>
<th>Character</th>
<th>Health Points</th>
<th>Action (if form-score = 1)</th>
<th>Action (if form-score = 2)</th>
<th>Action (if form-score = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knight</td>
<td>1000</td>
<td>200 / NREPS damage to one front-row target.</td>
<td>350 / NREPS damage to one front-row target.</td>
<td>500 / NREPS damage to one front-row target.</td>
</tr>
<tr>
<td>Wizard</td>
<td>750</td>
<td>100 / NREPS damage to primary target.</td>
<td>200 / NREPS damage to primary target; 100 / NREPS damage to random second target.</td>
<td>300 / NREPS damage to primary target; 200 / NREPS damage to random second target; 100 / NREPS damage to random third target.</td>
</tr>
<tr>
<td>Ninja</td>
<td>500</td>
<td>200 / NREPS damage to one target</td>
<td>300 / NREPS damage to one target</td>
<td>400 / NREPS damage to one target</td>
</tr>
<tr>
<td>Doctor</td>
<td>500</td>
<td>200 / NREPS healing to one target</td>
<td>350 / NREPS healing to one target</td>
<td>500 / NREPS healing to one target</td>
</tr>
</tbody>
</table>

Table 3-1 A breakdown of all characters in Bootle Rumble, their maximum health points, and their per-repetition action for form scores of 1, 2, and 3. Let NREPS be the number of repetitions for the exercise being performed in the current rumble phase. By dividing characters’ actions by the number of repetitions, we can define a maximum and minimum effect for each rumble phase. For example, the ninja can deal at least 200 damage, and at most 400 damage, per rumble phase. Note that the Knight is restricted to targeting enemies in the front row only.
perform the most repetitions of a given exercise in some amount of time. A game such as this would incentivize exercise, but would have the unintended consequence of incentivizing completing repetitions as quickly as possible, at the cost of form. Therefore, we designed Bootle Rumble with the intention of incentivizing *high-quality* exercise.

The goal of motivating proper form led to the inclusion of the form-tracking mechanic. While players perform repetitive exercise, a form score from 1-3 is assigned to each repetition. This form score influences the effectiveness and visual effect of in-game actions. As an example of this, Figure 3-6 shows the visual difference between form scores of 1, 2, and 3, in the Knight’s attack. Form scores are also paired with voiceover audio: Form scores of 1 are paired with “Okay!”; form scores of 2 are paired with “Good!”; form scores of 3 are paired with “Perfect!”.

These visual and auditory cues are intended to give players real-time feedback, as well as to make the player aware that their performance affects the outcome of the game.

There is also a strategic benefit to high-quality exercise: If the player achieves a perfect set (i.e. level 3 on all repetitions), the Knight deals 500 damage in one turn; If the player achieves level 2 on all repetitions, the Knight deals 350 damage; If the player achieves level 1 for all repetitions, the Knight deals 200 damage. A player may get different form scores on each repetition.

![Figure 3-6](image)

*Figure 3-6* The visual difference in the Knight’s attack based on form score. A form score of 1 produces small text, very little particle effect, and a grey colour (left). A form score of 2 produces midsized text, some particle effect, and a yellow colour (centre). A form score of 3 produces large text, a large particle effect, and a red colour (right).
repetition, resulting in a set that deals somewhere between 200 and 500 damage. Therefore, a player who focuses on high-quality exercise will deal more damage than one who does not. Ideally, the strategic advantage of higher form scores, combined with more engaging attack animations and more motivating voiceover audio, will sufficiently incentivize high-quality exercise.

During the rumble phase, players are shown an animation of the character Botley performing their prescribed exercise. Simultaneously, the visual layout changes to display a mirror image of the player while they exercise via a webcam. This mirror image allows players to monitor their own form while they exercise. Furthermore, it allows them to compare their quality of exercise to that of Botley, which they may use as a benchmark for their own exercise. These two game mechanics in combination with the form-tracking mechanic intend to allow the player to self-correct their own quality of exercise during play. This could have a beneficial effect on the quality of exercise of players.

3.2 Balancing for Different Ability Levels

A major design goal in Bootle Rumble was ensuring that the game was balanced for effort rather than physical ability, as recommended by Hernandez et al. [16]. In other words, we wanted the outcome of a game of Bootle Rumble to be independent of the players’ individual ability levels. We attempted to accomplish this by (1) using custom exercise regimens for each individual player, and (2) providing form feedback with knowledge of each individual’s ability level.

People with cerebral palsy have a wide range of ability levels. Cerebral palsy is classified based on two scales: The Gross Motor Function Classification System (GMFCS), and the Manual Ability Classification System (MACS). These scales are further described in Chapter 2.1. Our goal was for Bootle Rumble to be playable by anyone with GMFCS and MACS levels of I, II, or
III. We made this decision because the needs of people with GMFCS and MACS levels of IV or higher have greater therapeutic needs than those with lower levels, as well as greater impairments which would make playing an exercise game infeasible for them. We also wanted to ensure that the outcome of a game of Bootle Rumble is decided based on the strategy and effort of the players, rather than their physical abilities.

Bootle Rumble’s rumble phase is fully customizable based on the abilities of the player. The exercises shown in-game for a given player are prescribed prior to gameplay by a physiotherapist who is familiar with the player’s abilities and rehabilitation goals. An example exercise regimen for a participant in our Bootle Rumble pilot study is shown in Table 3-2. As it is a two-player game, Bootle Rumble allows each player to use an exercise regimen customized to their own abilities, as long as the total number of sets in each regimen is equal. Once both players’ exercise regimens have been exhausted, the game ends and a winner is declared. By providing separate, custom regimens for the two players, we limit the effect of players’ physical abilities on the outcome of the game. Furthermore, the physiotherapist who provides the exercise regimen for a given player also devises a rubric which can be used during gameplay to ensure fair and accurate form-scoring on a case-by-case basis. In this way, we attempt to ensure that the game is balanced based on the effort of the players, rather than their physical abilities.

### Exercise Regimen for Participant Bear

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Modifications</th>
<th>Sets</th>
<th>Reps Per Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion</td>
<td>Sitting in Chair</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Calf Strengthening</td>
<td>With Support</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Hip Abduction Strengthening</td>
<td>With Support</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Hip Flexor Strengthening</td>
<td>Hands Free</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Squats</td>
<td>Hands Free</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3-2 An example of an exercise regimen. This regimen was prescribed to a child with CP who participated in the Bootle Rumble study, codenamed Bear. Exercises are arranged alphabetically, and not in order of importance.
3.3 Considering the Needs of Youth With Cerebral Palsy

Depending on their MACS level, people with CP may have difficulty providing game input using a traditional controller/control scheme [1, 10]. People with CP may also have more deficits in visual-spatial processing [21]. We took these attributes into consideration in the design of Bootle Rumble, resulting in four design decisions: (1) turn-based gameplay, to eliminate the need for precise timing of input, (2) a control scheme with redundant button mappings to aid accessibility, (3) a sparse visual layout to reduce the need for complex visual-spatial processing, and (4) reinforcement of the game state using visual, text, and audio cues.

Our primary consideration regarding accessibility of Bootle Rumble was ensuring that children and youth with cerebral palsy would be able to reliably provide game input. This resulted in Bootle Rumble’s turn-based gameplay, which is at the core of the game itself. By making the gameplay turn-based, we remove any need for precisely-timed game input, which contributes to accessibility for people with motor disabilities [11].

The control scheme of Bootle Rumble was also designed to accommodate people with motor disabilities. In the design stage, we considered three potential input devices: (1) a Microsoft Kinect [24] for motion controls, (2) a touch device for touch-screen controls, and (3) a traditional Xbox 360 controller. We decided against motion controls as we felt that it was overly complicated, and not compatible with the simple selections required to play Bootle Rumble. In Bootle Rumble, players often need to put down the controller to perform exercise, and pick it back up to make strategic choices. We decided to use a Logitech F710 wireless gamepad for game input [22] as it is inexpensive and lightweight, allowing users to pick up and put down the controller easily and inexacty.

Bootle Rumble requires only three separate actions to play: (1) players must be able to navigate between the game’s characters, (2) they must be able to select characters, and (3) they must be able to cancel a selection. To ensure that children and youth with CP could use the
controller, we devised a control scheme which separates inputs for different actions to avoid accidental inputs, and has redundant inputs to allow users to provide input the way they want. The control scheme for Bootle Rumble is provided in Figure 3-7.

We wanted to make it easy for youth with CP to understand the visual output provided by Bootle Rumble. Figure 3-8 shows a comparison between Bootle Rumble and “Brains & Brawn”, an earlier game designed for typically-developing players discussed in Chapter 2.5. Bootle Rumble’s user interface is comparatively sparse, to avoid confusion. We also provide as much

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**Figure 3-7** A visualization of the control scheme of Bootle Rumble, with redundant button mappings: both the left stick and D-pad can be used to navigate through selectable items; all front-facing buttons on the right side can be used to accept selections; both the left and right bumpers on the top are used to go back and revise previous selections.

**Figure 3-8** A comparison between the user interfaces of Bootle Rumble (left) and Brains & Brawn [37,38] (right).
visual and auditory information about the game state as possible for players to refer to. For example, whenever the game state changes, a voiceover tells the player what to do next: “Choose a friend!”, “Choose a foe!”, etc. Players can also read the screen to see what to do next, view their current selections, or determine the health of their friends and foes. The teams in the game are also denoted by green and purple, two colors which appear distinct to players with almost all forms of color-blindness. The visual layout of Bootle Rumble is shown in Figure 3-2. Figure 3-9 shows a visualization of Bootle Rumble’s layout as it would be seen by players with various forms of color-blindness, using an online tool called CoBLIS [7].

3.4 Designing for Fun

The design of Bootle Rumble intends to balance the constraints of (a) promoting high-quality exercise, (b) balancing for different ability levels, and (c) considering the needs of youth with CP, without sacrificing the fun of the game. We attempt to make Bootle Rumble fun by (1) allowing players the opportunity to make meaningful choices during gameplay, and (2) using the illusion of randomness in instances where players are not free to make choices.

Figure 3-9 Visualizations of Bootle Rumble’s user interface from the perspectives of users with different types of color-blindness: (1) Protanomaly; (2) Deuteranomaly; (3) Tritanomaly; (4) Protanopia; (5) Deuteranopia; (6) Tritanopia. Visualizations were generated using CoBLIS [7].
There have been many attempts to gamify rehabilitation exercise for youth with CP, but a common trait of these games is that they sacrifice game-like quality for the sake of therapeutic benefit. Richards and Graham state that a major component in the enjoyment of video games is agency: the ability to make meaningful choices [38]. This ability to choose extends beyond simply the choice to perform an action correctly or incorrectly; the player should feel like they have true control over the state of the game. Take, for example, the “Dodgewall” game described in section 2.2, in which players position their bodies to fit through a hole in a virtual wall [26]. Beyond the choice to either play or not play, there are no meaningful choices for the player to make. This game could potentially be improved by providing multiple holes for the player to choose from. In this way, the player would feel that they have some control over the state of the game, as well as their own rehabilitation. Our design approach is novel in that Bootle Rumble is, first and foremost, a game. Our goal was to balance all design constraints without sacrificing game-like quality, and the most important element of that game-like quality is agency.

First, we wanted to ensure that Bootle Rumble provides agency. Bootle Rumble accomplishes this by dividing gameplay into the strategy phase and the rumble phase. In the strategy phase, players can safely make strategic choices without risk of making dangerous choices in the rumble phase. We maintain the therapeutic value of the game without sacrificing player agency, as outlined by Richards and Graham [38].

Second, to increase feelings of agency for players, we disguise any decisions that are not made by players (such as the exercise lists defined by physiotherapists) as random chance. In Bootle Rumble, the activity wheel provides the illusion of randomness at a time where it may not be safe for the player to make a choice. In this way, the order of exercises can be directly controlled by the physiotherapist, without making the player feel like their gameplay is being controlled by external forces. We foster agency without sacrificing the therapeutic value of the game.
In this chapter, we have outlined the gameplay of Bootle Rumble, and discussed the four primary considerations that were taken into account in its design: (1) promoting high-quality exercise by providing visual, auditory, and strategic benefits in-game for players who perform exercise with greater form; (2) balancing the game for varying ability levels by using custom exercise regimens for each player and considering their individual physical abilities during form scoring; (3) considering the specific population of youth with CP in the design of the game’s control scheme and visual layout, and reinforcing important information with visuals, text, and audio; (4) ensuring that the game remains fun by fostering player agency, and using the illusion of randomness to hide moments in which players are not able to make choices. In the following chapter, we will outline the study that we devised to learn more about the efficacy of Bootle Rumble’s form-tracking mechanic.
Chapter 4
Evaluation

We devised a pilot study with the intent of learning more about the effectiveness of Bootle Rumble’s design decisions, with a focus on the form-tracking mechanic. The pilot study was conducted at the Holland Bloorview Kids Rehabilitation Hospital (HBKRH), with approvals from the Queen’s University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (Appendix I) and the Holland Bloorview Research Ethics Board (Appendix J). Our pilot study aimed to explore three research questions: (RQ1) Does the presence of the form-tracking mechanic in Bootle Rumble improve players’ quality of exercise? (RQ2) Do participants enjoy playing Bootle Rumble? (RQ3) How effective are Bootle Rumble’s design decisions with respect to quality of exercise, accessibility, game balance, and fun?

4.1 Study Overview

We recruited three participants with cerebral palsy, with motor abilities classified at GMFCS levels I to III, and of ages 8-12 years to play two versions of Bootle Rumble; one with the form-tracking mechanic, and one without. Each participant took part in one session. In each session, participants played Bootle Rumble in dyads. A physiotherapy assistant (PTA) was present to provide form scores and ensure safety throughout each session. The PTA was aware of whether the form-tracking mechanic was present. After each game, participants answered two short, validated questionnaires regarding exertion and enjoyment—The OMNI Perceived Exertion Scale [39] (See Appendix A), which measures self-reported exertion levels, and the Self-reported Experiences of Activity Settings (SEAS) questionnaire [19] (See Appendix B), which measures youth experiences on five subscales: Personal Growth (PG), Psychological Engagement (PE), Social Belonging (SB), Meaningful Interactions (MI), and Choice and Control (CC). The PTA also answered a short custom questionnaire about their observations during study
sessions regarding quality of exercise. We conducted interviews at the end of each session with the participating youth with CP to learn more about their experience playing Bootle Rumble. We also concurrently conducted separate semi-structured interviews with their parent/guardians to learn more about their attitudes towards physiotherapy and rehabilitation exercise from a client’s perspective. At the end of the study, we conducted a semi-structured exit interview with the participating PTA to learn more about general attitudes towards rehabilitation exercise and youth with CP from the perspective of a care provider.

4.2 Participants

Our study involved three groups of participants: (1) participating youth with cerebral palsy, who each played two conditions of Bootle Rumble, completed questionnaires and took part in a semi-structured interview; (2) the parent/guardians of the participating youth with CP, who each took part in a semi-structured interview; and (3) A participating physiotherapist’s assistant, who provided form scores during gameplay, answered a short custom questionnaire at the end of each session, and took part in an exit interview at the end of the study.

Participating youth with CP were recruited internally at the Holland Bloorview Kids Rehabilitation Hospital in Toronto, Ontario. We recruited three participants between the ages of 8 and 16 years, with cerebral palsy, and classified at level I-III on both the Gross Motor Function Classification System (GMFCS) and the Manual Ability Classification System (MACS). All three participants were male, and had experience with video games and controllers. Each participant was assigned a codename: Bear, Tiger, and Lynx. The participants will hereafter be referred to by these codenames. Participants Bear and Tiger played together in one session. Participant Lynx played with his typically-developing siblings in a different session. Lynx’s typically-developing siblings participated in gameplay, but their data was not collected. Participating parent/guardians were recruited along with their children. The participating PTA was an employee of Holland Bloorview Kids Rehabilitation Hospital.
4.3 Setup and Apparatus

The setting for our study is shown in Figure 4-1. When performing exercise, participants stood in the center of the room. When not performing exercise, participants sat in two chairs positioned outside of the exercise area, while the physiotherapist was positioned with a wireless keyboard on the side of the exercise area. Bootle Rumble was displayed on a mobile widescreen TV at the front of the room.

4.4 Conditions

We tested Bootle Rumble with two different conditions: the control condition in which the form-tracking mechanic was disabled, and the experimental condition in which the form-tracking mechanic was enabled. In both conditions the physiotherapist inputted form scores for logging purposes, but only in the experimental condition did the form scores affect gameplay. In the control condition, in-game actions were random (i.e. all characters’ actions perform a random amount of damage/healing regardless of quality of exercise), whereas in the experimental

![Figure 4-1](image-url)  
Figure 4-1 The setting for the Bootle Rumble pilot study. The room was arranged as follows: (1) A television positioned at one end of the room, from which Bootle Rumble was displayed, and a webcam; (2) two chairs facing the television (one for each participant); (3) a chair for the participating PTA; (4) the exercise area, defined by the field of view of the webcam.
condition, in-game actions’ effectiveness depend on the form score reported by the physiotherapist (i.e. higher form scores result in greater damage/healing and more extravagant animations than lower form scores).

The participants completed the control condition, followed by the experimental condition. We did not order-balance the conditions; we hypothesized that if the experimental condition were played first, participants would become accustomed to the form-tracking mechanic, only for it to be removed in the control condition. Participants may not be fully aware of the removal of the mechanic, which could have an unwanted effect on our results. To limit the learning effect, we began each session with a 10-minute gameplay tutorial.

4.5 Measures

During each rumble phase of gameplay, the form scores reported by the physiotherapist were logged to a file for later analysis. We wrote a custom log analyzer to determine the average form score for each condition. After the completion of each condition, participants answered the OMNI perceived exertion scale [39] and the SEAS questionnaire [19]. After each session, the physiotherapist answered a short questionnaire regarding their observations during the session.

4.5.1 SEAS Questionnaire

The Self-Reported Experience of Activities Settings (SEAS) Questionnaire measures participants’ experience when participating in leisure activities. The questionnaire is composed of 22 questions, categorized into five subscales: Personal Growth (PG), Psychological Engagement (PE), Social Belonging (SB), Meaningful Interactions (MI), and Choice and Control (CC). SEAS questions are presented in seven-point Likert Scale format. The SEAS scoring is inverted (lower scores reflect a more positive response than higher scores). A blank SEAS Questionnaire is provided for reference in Appendix A [19].

4.5.2 OMNI Perceived Exertion Scale
The OMNI Perceived Exertion Scale captures self-reported exertion levels on a scale from zero to ten. The scale includes images to illustrate the different exertion levels. Many OMNI scales exist with different images to suit different contexts. We provide the OMNI Perceived Exertion Scale that was used in the Bootle Rumble study in Appendix B [39].

4.5.3 Custom PTA Questionnaire
We devised a short custom questionnaire to be administered to the participating PTA at the end of each session, in order to capture information about the quality of exercise they observed during the session. The questionnaire is composed of two Likert scale questions and three short-answer questions. The custom questionnaire administered to the participating PTA is provided in Appendix C.

4.5.4 Semi-Structured Interviews
Semi-structured interviews are interviews which are “generally [organized] around a set of predetermined open-ended questions, with other questions emerging from the dialogue between interviewer and interviewee” [8]. We conducted semi-structured interviews with each participant at the end of each session to capture their opinions on Bootle Rumble and its game mechanics. We also conducted semi-structured interviews with the parent/guardians of participants at the end of each session, in order to learn more about general attitudes towards rehabilitation for youth with cerebral palsy from a client’s perspective. Finally, at the end of the pilot study, we conducted a semi-structured interview with the participating PTA to learn more about attitudes regarding rehabilitation for youth with CP from the perspective of a physiotherapy professional. The full semi-structured interview scripts for participating youth with CP, their parent/guardians, and the participating PTA are provided in Appendix D, E, and F, respectively.
4.6 Procedure

Pairs of participants attended one session of approximately two hours in length. Bear and Tiger were paired together in the first session. In the second session, Lynx played against his own typically-developing siblings. Participants played Bootle Rumble’s control build for 10 minutes as a tutorial. The game was then restarted, and participants played the control condition for 20 minutes (roughly 8 turns each). Participants then answered the OMNI exertion scale and the SEAS questionnaire. Participants were then informed that the experimental condition was about to begin, in which better quality of exercise makes attacks stronger. Participants then played the experimental condition for 20 minutes (roughly 8 turns each), followed by answering the OMNI exertion scale and SEAS questionnaires. The physiotherapist then answered a short custom questionnaire about their observations.

During each session, the parent/guardians of participants took part in a semi-structured interview. At the end of the session, each pair of participants took part in a semi-structured interview as well. At the end of their participation in the study, the participating PTA took part in a semi-structured interview about rehabilitation for kids with cerebral palsy in general.
Chapter 5

Results

In this chapter, we report participants’ responses to the SEAS Questionnaire, their perceived exertion as recorded via the OMNI perceived exertion scale, and their average form scores recorded in each condition. We also report responses gathered in semi-structured interviews with participants, their parent/guardians, and the participating PTA.

5.1 SEAS Questionnaire

After playing each condition, we asked participating children to complete the Self-Reported Experience of Activities Settings (SEAS) questionnaire.

Figure 5-1 Subscale scores from the SEAS questionnaire for each participant, and the average score for each subscale. SEAS scoring is inverted (lower scores reflect a more positive response than higher scores).
Figure 5-1 shows each participant’s scores for each subscale of the SEAS Questionnaire. Lynx chose not to answer three questions in the Personal Growth subscale, which is why his scores for Personal Growth and Average Response are not reported. Apart from the Personal Growth subscale, participants had positive responses to the SEAS questionnaire: On the Social Belonging subscale the mean score was 1.3; On the Psychological Engagement subscale the mean score was 1.4; On the Choice and Control subscale the mean score was 1.5; On the Meaningful Interactions subscale the mean score was 2.5; And on the Personal Growth subscale the mean score was 3.75.

Figure 5-2 shows participants’ individual responses to the SEAS questionnaire using a diverging stacked bar chart [31]. A diverging stacked bar chart organizes responses around a vertical baseline, such that positive responses fall to the right of the baseline, and negative responses to the left [31]. With this visualization we can examine participants’ responses with more granularity: Questions in the Personal Growth subscale were met with the most negative responses of the subscales, with four negative responses of varying strength, though the overall response was still more positive. The Meaningful Interactions subscale had one negative response.

![Participant SEAS Responses (Stacked Divergent Bar Chart)](image)

Figure 5-2 A diverging stacked bar chart visualizing participant responses to SEAS questions in each of the five subscales: Personal Growth (PG), Psychological Engagement (PE), Social Belonging (SB), Meaningful Interactions (MI), and Choice and Control (CC).
and one neutral response. For the other three subscales, participants gave varying degrees of positive responses, but zero negative or neutral responses.

5.2 OMNI Perceived Exertion Scale

After playing each condition, we asked participants to score their perceived exertion using the OMNI Perceived Exertion Scale. Figure 5-3 shows each participant’s perceived exertion as measured by the OMNI Scale after each condition, as well as the average perceived exertion of all participants after each condition. Two of the three participants reported higher exertion in the experimental condition than the control condition, while one participant reported equal exertion in both conditions.

5.3 Form Scores

During gameplay, a participating PTA evaluated players’ quality of exercise, and provided form scores of 1-3 to reflect the observed form (refer to Chapter 3.1 for more details about form scores). In the control condition, the form-tracking mechanic was disabled, and the form scores were recorded for analysis only. In the experimental condition, the form-tracking

![Figure 5-3 Participants’ responses to the OMNI Perceived Exertion Scale after playing through each condition.](image)
mechanic was enabled, and the form scores were used in-game to determine the quality of in-game actions (refer to Chapter 3.1 for more details about the form-tracking mechanic).

Figure 5-4 shows the average form scores for each participant for each condition, as well as the average form score of the participants for each condition: Bear’s average form score decreased from 2.31 in the control condition to 1.88 in the experimental condition; Tiger’s average form score increased from 1.79 in the control condition to 1.92 in the experimental condition; Lynx’s average form score decreased from 2.67 in the control condition to 2.60 in the experimental condition.

5.4 Physiotherapist Questionnaire

After each study session, we asked the participating PTA to complete a custom questionnaire with the intention of learning more about the quality of exercise that the PTA observed during the session. Table 5-1 shows the PTA’s responses to this questionnaire after each session.
5.5 Participant Interviews

After each study session, we asked each participating child to participate in a semi-structured interview to learn more about their experience playing Bootle Rumble. Table 5-2 shows the participants’ responses from these interviews, converted to numerical or Likert scale values where possible.

In response to the question “Would you play this game at home?”, one participant responded positively, while the other two responded with neutral sentiments.

<table>
<thead>
<tr>
<th>Participant Interview Question</th>
<th>Bear</th>
<th>Tiger</th>
<th>Lynx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you agree with the statement “I would play this game at home.”?</td>
<td>Neutral/Negative</td>
<td>Neutral/Negative</td>
<td>Yes</td>
</tr>
<tr>
<td>Which version did you prefer?</td>
<td>Control</td>
<td>Experimental</td>
<td>Experimental</td>
</tr>
<tr>
<td>How would you describe the game’s fairness?</td>
<td>Fair</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>How would you describe the game's difficulty?</td>
<td>Hard</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td>Did you like the webcam mirror?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Did you find Botley helpful?</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Did you find the controls easy to use?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 5-2 Participants’ responses to questions posed in their semi-structured interviews, simplified into short answers.
Bear said “I wouldn’t, like, actively, like not every day, but sometimes.” He provided his rationale for this statement: “… It doesn’t seem that appealing, um, looking to my other games that I have.” Bear went on to suggest adding more strategic elements to the game: “… More characters, strategy. More strategy. Like different attacks… [you] can encounter characters, can do more damage on different characters, and … some attacks would be weaker, and some characters have a set level of attacks that they can do…”

Tiger said “So-so”, and provided his rationale: “… It’s not really my style.” He continued to say “Not really. But I would, but maybe just once in a while game.” He suggested that changing the style of the game by “[making] it more sporty” or “a Mario version” might make him want to play it at home.

Lynx said “I [would play at home, but only if] you to use the [experimental version] …’cause then it will teach people that they have to do work for this.” When asked why he would play the game at home, Lynx responded, “Because I think it’s … a great way for kids with disabilities like myself to get exercise and fun.”

In response to the question “Which version [of Bootle Rumble] did you prefer?” two participants preferred the experimental version, and one participant, Bear, preferred the control version. Bear said “I preferred [the] one which is random… because it’s… easier, and it’s more surprising to see what you get.” Tiger preferred the experimental version, with the rationale that “It had the exercises that I really do at home.” Lynx also preferred the experimental version, saying “I preferred… the one where you have to work for it,” because “it tells people ‘you have to… be working hard for this.”

Regarding the game’s fairness, all three participants agreed that the game was fair. Bear was the only participant to state that the control version of the game was more fair than the experimental version, remarking “I think it was pretty fair. Especially for the the [control
version]… For the [experimental version], it mostly comes down to the person you’re [playing] against.”

Regarding the game’s difficulty, two participants responded that the game had “medium” or “neutral” difficulty, and one participant, Bear, responded that the game was “hard”. Tiger said the difficulty was “medium”, and was very focused on the exercise element of the game, stating “Some exercises were a little bit hard, and some exercises were very easy.” He did not comment on the strategic elements of the game. Lynx responded that the game was “neutral”, elaborating that “[As a player], you did all the things, but didn’t realize it because you were having so much fun.” Bear said the game was “hard, especially the [experimental version] where, as I said, it wasn’t random, so… you have to exercise even more to get a perfect attack on someone.”

All three participants responded that they found the webcam ‘mirror’, displayed during the rumble phase, useful. Bear said “I liked that it… showed you if you… did one really bad or really good”, but noted a negative logistical element: “you have to constantly change the camera angle”. Tiger said “I really liked it because… you can see what you’re doing… it makes it easier… to do the exercises.” Lynx said “I liked that I could see how to improve [my form] in the game.”

In response to the usefulness of the character Botley who performs exercise along with players in-game, two out of three responded that Botley was useful, while one participant, Tiger, responded that he was not. Bear said “I found it useful, especially if you didn’t have someone to help you,” but noted that “It might not be the best way because you can’t really see sometimes.” Lynx thought Botley was useful, saying “It showed you how to make [your form] better, by going slow.” Tiger did not think Botley was useful “[because] I already do the exercises at home,” and suggested “maybe you could… hide [Botley] and show [him]… sometimes.”

All three participants responded that they found Bootle Rumble’s control scheme easy, and stated that they had prior experience with using game controllers.
5.6 Parent/Guardian Interviews

After each study session, we asked the parent/guardian of each participating child to participate in a semi-structured interview to learn more about their general attitudes towards physiotherapy and rehabilitation exercise for youth with CP. Table 5-3 shows participating parent/guardian responses from these interviews, converted to numerical or Likert scale values where possible. Further analysis of parent/guardian responses is available in Chapter 6.

To the question “Does your child come into the hospital or any other clinic to do rehabilitation exercises, and if so, how frequently?”, two participating parent/guardians responded that their child does in-clinic rehabilitation frequently, while Tiger’s parent/guardian responded “not very frequently”. Bear’s parent/guardian responded that Bear does rehabilitation at the

<table>
<thead>
<tr>
<th>Parent/Guardian Interview Question</th>
<th>Bear’s parent/guardian</th>
<th>Tiger’s parent/guardian</th>
<th>Lynx’s parent/guardian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of in-hospital/clinic rehabilitation?</td>
<td>20 times per year</td>
<td>3 times a year, + research</td>
<td>Frequent</td>
</tr>
<tr>
<td>Have you been prescribed at-home exercise?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Who prescribed them?</td>
<td>Therapist, strength training specialist</td>
<td>Therapist, Personal Trainer</td>
<td>PTs, Conductive Educators</td>
</tr>
<tr>
<td>Circumstances of exercises?</td>
<td>All of the above</td>
<td>Homework from in-clinic rehab</td>
<td>Extend movement</td>
</tr>
<tr>
<td>How often does your child perform at-home rehab?</td>
<td>Frequently -- 4-5 times per week</td>
<td>Frequently -- 3-4 times a week</td>
<td>Rarely -- Used to be every day, now it's rare</td>
</tr>
<tr>
<td>What gets in the way of rehab exercises?</td>
<td>motivation</td>
<td>fatigue</td>
<td>family logistics</td>
</tr>
<tr>
<td>What might help your child to perform their at-home exercises more frequently?</td>
<td>motivation</td>
<td>nothing – he likes it</td>
<td>motivation</td>
</tr>
<tr>
<td>Does your child enjoy at-home exercise?</td>
<td>No – they’re boring</td>
<td>Yes – very active</td>
<td>Neutral – Sees value, would prefer other activities</td>
</tr>
</tbody>
</table>

Table 5-3 The parent/guardians’ responses to questions posed in their semi-structured interviews, simplified into short-answer responses.
hospital “a couple of times… a year for ten sessions each time… so about 20 [times per year].” Lynx’s parent/guardian said “Very frequently. Usually he has a couple of blocks of therapy a year where he’s coming once a week and… he’s doing [occupational therapy and physiotherapy], he’s involved in studies and stuff, and, sees his doctor… He occasionally does conductive [education at a clinic]” Tiger’s parent/guardian said “He does come… but not very frequently… We always come in for checkups, maybe… two or three times a year, and then we always come for research and things like that.”

In response to the question, “Has your child ever been assigned rehabilitation exercises to perform at home?” all parent/guardians responded “Yes”.

To the question, “Was the person who assigned these exercises a therapist? (If no, then who?)”, each parent/guardian responded differently. Bear’s parent/guardian said Bear had been prescribed at-home rehabilitation exercise by “a therapist… as well as a strength training specialist… [a personal trainer.]” Tiger’s parent/guardian said “[Tiger] has been assigned [rehabilitation exercise by occupational therapists and physiotherapists].” Lynx’s parent/guardian said “[Lynx has] had them assigned by therapists here at Bloorview, and… conductive educators.”

To the question “What were the circumstances of these exercises (e.g. following surgery, to extend range of movement, to maintain fitness, etc...)?”, parent/guardians had varying responses. Bear’s parent/guardian responded “All of the above… we had some that were to help with range of movement, some to maintain fitness, and he had major surgery as well, so that’s post-surgical.” Tiger’s parent/guardian responded “Most of them [were]… to maintain… like after a session… we get some homework to do…” Lynx’s parent/guardian responded that most at-home rehabilitation exercise prescriptions are for “stretching and building muscle, and… using exercise to try and extend movement.” She elaborated that “[Lynx’s] exercises aren’t specific
‘hey we’re [going to] do ten reps,’ it’s like activities of daily living, it’s like, ‘okay we’re going to the washroom, let’s walk to the washroom,’ that kind of thing.”

In response to the question “How often does your child perform these exercises?”, each parent/guardian had a unique response. Bear’s parent/guardian responded “… at least four to five times a week”. Tiger’s parent/guardian responded “… almost… three or four times a week”. Lynx’s parent/guardian responded “In the past… when he was… two, three [years old], we really tried to maintain a regular schedule where he was doing a little bit every day… [but] it’s not really plausible… in our household at the moment”.

In response to the question, “Does anything get in the way of your child performing their at-home exercises?” parent/guardians mentioned differing barriers to exercise. Bear’s parent/guardian responded jokingly, “Yes, the child,” and elaborated, “their mood, their cooperation level.” Tiger’s parent/guardian said “No, he’s very motivated… Sometimes like after school he gets tired… [but] most of the time he’s good to do it, yeah.” Lynx’s parent/guardian said “Time, schedule, number of children requiring mom’s attention… Logistics [of raising a family].”

In response to the question, “What might help your child to perform their at-home exercises more frequently?”, two of three parent/guardians (Bear’s and Lynx’s) responded that greater motivation would be effective, while one parent/guardian (Tiger’s) responded that Tiger is already motivated to perform his rehabilitation exercise. Bear’s parent/guardian said, “The video game [Bootle Rumble] was a nice reward system, so that was obviously, just from looking in on the session, really motivating.” Lynx’s parent/guardian said, “Proper motivation… when [I’m] trying to make dinner and do laundry and get everyone’s homework done, [I don’t] wanna fight about it.” Tiger’s parent/guardian said, “… For [Tiger], it’s something very natural… he asks to do it… He has interest… But I think… [doing it] together… as a family… always helps [him].”
In response to the question, “Does your child enjoy performing at-home exercises?”, two of three parent/guardians (Bear’s and Lynx’s) responded negatively, while one parent/guardian (Tiger’s) responded positively. Bear’s parent/guardian said “No…[he thinks] they’re boring… I have to use rewards a lot, to get [him] to complete [rehabilitation exercise]… [Bear is] a performer, so if there’s applause or some kind of… score-keeping… he tends to perform more… and the video game [Bootle Rumble] kinda gave him the same feedback.” Tiger’s parent/guardian said “he loves them… when we don’t do it, he’s always the first one to [say] ‘What’s going on with you people,’ like ‘what am I doing today?’ … He’s very competitive… he wants to win everything… I think it’s very good … [because] the hard thing I think is to get them motivated right?” Lynx’s parent/guardian said “[Lynx] is very smart, and he sees the value of exercises as ‘this is [going to] help me with this’ … he’s determined to do [rehabilitation exercises] and he does them but I’d say if he could choose to do something else, he would.”

5.7 Physiotherapist Interview

After both study sessions were completed, we asked the participating physiotherapist’s assistant to participate in a semi-structured interview to learn more about physiotherapy and rehabilitation exercise for youth with CP in general. Table 5-4 shows the participating PTA’s responses from these interviews, converted to numerical or Likert scale values where possible. Further analysis of the PTA’s responses is available in Chapter 6.

In response to the question “Is physiotherapy and/or occupational therapy important for children and youth with CP? Why or why not?”, the participating PTA responded, “Absolutely, 110%... Just in terms of function, and future, and fun and also the ability to just function on things on a daily basis, like, you know, going to the washroom, brushing your teeth, getting up in the morning, walking.”

In response to the question “Can you briefly reflect on the importance of physio- and occupational therapy for children and youth with CP? Are there particular situations where they
Is physiotherapy and/or occupational therapy important for children and youth with CP? Why or why not? | Yes, absolutely.
---|---
Can you briefly reflect on the importance of physio- and occupational therapy for children and youth with CP? Are there particular situations where they are most important? | Important throughout lifetime.
What resources are available for children to come into the hospital to perform rehab in the presence of a physiotherapist? | Saturday morning circuit training program, with ongoing participants.
How often do you prescribe or recommend rehabilitation exercises for kids with CP to perform at home? | Depends on the concerns of the individual/family.
What do you view as the role of therapy at home? Is this an adjunct to therapy in the clinic, or something that can be done standalone? Is home therapy something you use of necessity due to lack of resources to see everyone in clinic? | At-home therapy does save resources. Can also be an adjunct to in-clinic therapy.
If you do prescribe rehab exercises, how frequently do you ask children to perform the exercises you prescribe? what does a typical exercise prescription look like? | 20 to 30 minutes per day. Stretches, abdominal exercises, leg exercises, variety.
Are there sufficient resources to follow up with these kids to learn whether they are performing their exercises, or if the exercises are effective? | Not necessarily. Depends how often they see a PT.
Do you think the children with CP enjoy doing their rehabilitation exercises? | Probably not. It’s hard.
Do you think incorporating these exercises into a game such as Bootle Rehab would make them enjoy it more? | Absolutely. Part of being a PT is gamification of exercise.

Table 5-4 The participating PTA’s responses to questions posed in her semi-structured interview, simplified into short answers.

are most important?”, the participating PTA responded, “I would say most important… throughout a lifetime actually… When they are first diagnosed… just getting them into their typical movements of rolling… sitting up… just being able to… participate… [at] school, and as they get older, you gotta really think about it just like… any other type of youth, you know, obesity, and things like that, and cardiovascular diseases… especially with kids with CP, they have a lot more… health complications when it comes to… tightening muscles and things like that, so staying active and understanding… the importance of an active life… could really effect their life in the long run in a healthy way.”
In response to the question, “What resources are available for children to come into the hospital to perform rehab in the presence of a physiotherapist?”, the participating PTA responded, “So in our facility at Holland Bloorview… we have a program called Fit’n’Flex that runs [on] Saturday mornings… and it’s basically a circuit training… program. It’s two hours: an hour and a half of… exercises that are tricky and quite functional for… the CP population. For example, sidestepping, sit-to-stands, some standing balance… endurance and agility, and speed. And also just strengthening exercises [for] your core… and stretching as well. And then we also do some fun therapeutic rec activities at the end… that support all those movements… [The program is] ongoing… So a few of … the clients we’ve had, they’ve been in the program for … quite a few years now.”

In response to the question, “What do you view as the role of therapy at home? Is this an adjunct to therapy in the clinic, or something that can be done standalone? Is home therapy something you use of necessity due to lack of resources to see everyone in clinic?”, the participating PTA responded, “I would say yeah, in terms of … resources, that’s right… I would compare it to… [a typically-developing person] going to the gym. Do we really need to go to the gym… or can we do some home programming for ourselves, right? … If you have a mat, you can do a lot more, and you can do it at your own time. You don’t necessarily need to come and take the resources of the gym or whatnot… But it’s also an adjunct too, so… it could play a role… depending [on if] there’s surgery involved. And it depends if they’ve had [botox injections] … It depends where they’re at.”

In response to the question, “If you do prescribe rehab exercises, how frequently do you ask children to perform the exercises you prescribe? What does a typical exercise prescription look like?”, the participating PTA responded, “… I would say, at least once a day, um, at least 20 to 30 minutes per day … Physiotools, … [is] generally the program that we use, unless we just write it down… but [there are] photos on there, and it’s different … stretches, … different
abdominal exercises. It could be different leg exercises. Variety, right? But there’s photos and a
prescription at the bottom of [each exercise, outlining] sets and reps, as well.”

In response to the question, “Are there sufficient resources to follow up with these kids to
learn whether they are performing their exercises, or if the exercises are effective?”, the
participating PTA responded, “… Not necessarily … because it depends how often they’re seeing
their PT… It could be like, ‘okay you have to set an appointment, and you’ll see your PT in the
next 6 months.’ Right? So what’s happening in those 6 months? Do they forget to bring up the
fact that they’ve done the whole program? Does the PT remember? Does it even matter to
anybody in the end? … It’s the onus and the autonomy of … the client and the family to bring it
up too, right, so… it depends.”

In response to the question, “Do you think the children with CP enjoy doing their
rehabilitation exercises?”, the participating PTA responded, “… Probably not… I get a lot [of
clients] that say ‘we don’t enjoy it.’ … It’s hard to motivate, right? I find that finding that
motivational piece to do it, just like any other youth … without a disability… compare it to like,
gym class. Compare it to doing exercise at home by yourself … It’s a lack of motivation, I find.”

In response to the question, “Do you think incorporating these exercises into a game such
as Bootle Rehab would make them enjoy it more?”, the participating PTA responded,
“Absolutely … Even just in my practice alone, I am constantly being creative and trying to make
it as a game. Not necessarily a virtual reality game, but in a game in general to … mask the idea
that they’re doing these … sets of exercises but trying to make it fun, and that helps a lot.”

At the end of the interview, we asked the PTA an informal question about her
observations during study sessions with regards to form-tracking and quality of exercise: “… Do
you think the quality of exercise … improved … with the form-tracking mechanic [enabled] …
versus without?” The PTA responded, “Yes! Yes, absolutely … I could just see, like [a] lightbulb
went off too, right? … For [the second] session… yeah the quality improved … [and in the first] session … yes! For the most part, yes. When concentration was up.”

In this chapter, we have reported our results from the Bootle Rumble study. We have graphed the participants’ responses to the SEAS questionnaire and the OMNI exertion scale. We have shown the results of our custom questionnaire for the participating PTA’s assistant. We have summarized the responses from our semi-structured interviews with the participating youth with CP, their parent/guardians, and the participating PTA. In the next chapter, we will further evaluate those results with respect to our research questions.
Chapter 6

Analysis

Our results reported in Chapter 5 give us information about the experience of our three participating youths with CP. While a larger study would be required to draw definitive conclusions, we can draw tentative conclusions from this pilot study with respect to the research questions we asked in Chapter 4: (RQ1) Does the presence of the form-tracking mechanic in Bootle Rumble improve players’ quality of exercise? (RQ2) Do participants enjoy playing Bootle Rumble? (RQ3) How effective are Bootle Rumble’s design decisions with respect to quality of exercise, accessibility, game balance, and fun?

This chapter is divided into 6 sections. In section 6.1 we synthesize the information gathered in the semi-structured interviews with participants and their parent/guardians, to characterize each participant and provide additional context for their responses. In section 6.2 we examine the interviews with parent/guardians of participants and the participating PTA to learn more about their attitudes towards rehabilitation for youth with CP. In section 6.3 we evaluate Bootle Rumble’s effect on quality of exercise by examining participants’ form scores and responses to the OMNI Perceived Exertion scale, and the participating physiotherapists’ questionnaire and interview responses. Next, in section 6.4, we evaluate player enjoyment during play of Bootle Rumble by examining participants’ SEAS Questionnaire responses and interview responses. Finally, in section 6.5, we relate our results back to our design decisions for Bootle Rumble outlined in Chapter 3 to evaluate the effectiveness of those choices. In section 6.6 we summarize our analysis.
6.1 Participant Summaries

In this subsection we synthesize responses gathered in semi-structured interviews with the participants and their parent/guardians to provide further context for their questionnaire and interview responses. We also examine responses gathered during semi-structured interviews with our participating PTA, as well as the parent/guardians of participants, to better understand rehabilitation for youth with CP in general.

6.1.1 Tiger

Tiger is a twelve-year-old male whose motor function is classified at GMFCS level I. Based on the semi-structured interviews with Tiger and his parent/guardian, Tiger performs physical activity frequently. He performs at-home rehabilitation exercise three to four times per week. He is self-motivated to perform his rehabilitation exercises and is further motivated by his family members who commonly exercise together with him. He is also involved in extracurricular sports such as swimming and karate. Tiger has experience playing video games with handheld controllers. Tiger’s interview suggests that while playing Bootle Rumble, he was more focused on exercise than gameplay. For example, when asked what changes we should make to Bootle Rumble, he suggested that we “make it more sporty”, and expressed little opinion about the strategy of the game. Tiger played Bootle Rumble in a session with Bear.

6.1.2 Bear

Bear is a nine-year-old male whose motor function is classified at GMFCS level III. Semi-structured interviews with Bear and his parent/guardian revealed that Bear is an avid video game player, and has experience playing video games with handheld controllers. Bear is not intrinsically motivated to perform rehabilitation exercise, with his parent/guardian stating that he “finds them boring”. He still performs rehabilitation exercise “four to five times a week”. Bear’s parent/guardian stated that she uses rewards to motivate Bear to perform rehabilitation exercise. Bear’s interview suggests that while playing Bootle Rumble, he was more focused on gameplay
than exercise. For example, when asked what changes we should make to Bootle Rumble, he wanted “more characters [and] strategy”, and he preferred the control version of the game where gameplay is less reliant on quality of exercise. Bear played Bootle Rumble in a session with Tiger.

6.1.3 Lynx

Lynx is an eight-year-old male whose motor function is classified at GMFCS level III. According to semi-structured interviews with Lynx and his parent/guardian, Lynx “sees the value of [rehabilitation] exercise” but does not necessarily enjoy it. Lynx is experienced with playing video games with handheld controllers. Lynx does not regularly perform structured rehabilitation exercises but his parent/guardian stated that he does practice “activities of daily living”. Lynx’s parent/guardian stated that “proper motivation” would help Lynx perform at-home exercises more frequently. While playing Bootle Rumble, Lynx was more focused on gameplay than exercise, as he stated, “you were doing all the [exercises] but didn’t quite realize it because you were having so much fun.” However, unlike Bear, Lynx adamantly preferred the experimental version to the control version, because “it tells people ‘you have to be working hard for this’”. Lynx played Bootle Rumble in a session with his two typically-developing siblings.

In summary, our three participants for the Bootle Rumble pilot study can be summarized as follows: Tiger, a twelve-year-old male classified at GMFCS level I, who is involved in active extra-curriculars and is self-motivated to perform at-home rehabilitation exercise three to four times per week; Bear, a nine-year-old male classified at GMFCS level III, who is an avid video game player and is motivated via rewards to perform at-home rehabilitation exercise four to five times per week; Lynx, a eight-year-old male classified at GMFCS level III, who does not perform structured at-home rehabilitation exercise but does regularly practice activities of daily living.
6.2 Participants’ Attitudes Towards Rehabilitation for Youth with CP

In order to better understand the current state of rehabilitation for youth with cerebral palsy, and the position of Bootle Rumble, we conducted semi-structured interviews with our participating PTA and the families of our participating youth with CP.

In her semi-structured interview, our participating PTA stated that she would generally recommend that clients perform at-home rehabilitation exercise “at least once a day [and] at least 20 to 30 minutes per day”. However, none of the parent/guardians of our participating youth with CP reported that their child was performing at-home rehabilitation with such regularity: Tiger’s parent/guardian reported that Tiger performs at-home rehabilitation “three to four times a week”; Bear’s parent/guardian reported that Bear performs at-home rehabilitation “four to five times a week”; Lynx’s parent/guardian reported that Lynx is no longer prescribed, and does not regularly perform, structured rehabilitation exercise. The fact that no participating youth with CP meet the PTA’s recommended frequency of rehabilitation exercise suggests that some intervention, such as gamification via Bootle Rumble or a similar system, is needed to increase the regularity of at-home rehabilitation exercise for our participating youth with CP.

The PTA’s interview responses suggest that there are resources available for our participating youth with CP for in-clinic rehabilitation in Toronto. As an example, the PTA mentioned a circuit training program which runs every Saturday morning, where attending youth with CP perform rehabilitation exercise and recreational activities. She stated that some youth who participate in the program have been attending for “quite a few years”. However, while resources such as those offered by Holland Bloorview Kids Rehabilitation Hospital can be beneficial to youth with cerebral palsy, accessibility is largely dependent on the geographical locale and availability of those resources.

Interviews with parent/guardians of participating youth with CP showed that different children with CP have different needs regarding in-clinic rehabilitation, and therefore require
different resources. Lynx’s parent/guardian stated that Lynx comes to the hospital for in-clinic rehabilitation “very frequently. Usually he has a couple of blocks of therapy a year where he’s coming once a week … he’s doing OT PT [and] he’s involved in studies”; Lynx also participates in “conductive education” privately at another clinic. Bear’s parent/guardian made similar statements, stating that Bear performs in-clinic rehabilitation at the hospital “about 20” times per year, and does physiotherapy “privately … three to four times a week”. Conversely, Tiger’s parent/guardian stated that he only comes to the hospital for “checkups” and “research [studies]”, but is very active outside of clinical settings: “he takes karate class, swimming class, and [does other extracurricular activities]”. Tiger, whose motor abilities are classified at GMFCS level I, may require fewer clinical resources than Bear or Lynx, whose motor abilities are classified at GMFCS level III. Even among our small set of three participants, we see a variety of needs concerning in-clinic rehabilitation, but all three children require some physiotherapeutic resources. Furthermore, we see that all two of the three participants—Bear and Lynx, both having motor function classified at GMFCS level III—take part in some form of rehabilitation outside of Holland Bloorview Kids Rehabilitation Hospital, as an adjunct to their in-clinic rehabilitation. This suggests that while there are resources available to clients with CP at the Holland Bloorview Kids Rehabilitation Hospital, they may not be sufficient to meet all of the needs of every child with cerebral palsy.

Our participating PTA stated that physiotherapists often prescribe at-home rehabilitation exercises to youth with CP both as an adjunct to in-clinic rehabilitation and as a method for reducing the resources required for in-clinic rehabilitation. She compared people with CP participating in in-clinic rehabilitation to typically-developing people going to the gym: “Do we really need to go to the gym … or can we do some home programming for ourselves? … You don’t necessarily need to come and take the resources of the gym”. She stated that prescription of at-home rehabilitation exercises is “also an adjunct [to in-clinic rehabilitation] too … it could play
a role … depending [on if] there’s surgery involved”. Parent/guardians of participating youth with CP corroborated the statements of the PTA, stating that their children had been prescribed at-home exercises under many different circumstances. Bear’s parent/guardian stated that Bear had been prescribed exercise to “help with range of movement”, to “maintain fitness”, and for “post-surgical” maintenance. Tiger’s parent/guardian stated Tiger was usually prescribed at-home exercise as “homework” after in-clinic rehab sessions. Lynx’s parent/guardian stated that Lynx had been prescribed rehabilitation exercises “when he was younger” for functional reasons such as to “help him sit up, or stretch things.” The frequency and wide range of reasons for prescribing at-home rehabilitation exercises for youth with CP suggests that a game such as Bootle Rumble could be useful to many youth with CP, assuming that gamification is something that youth with CP want.

With regards to gamification, the PTA remarked that gamification is already used informally in the domain of rehabilitation exercise for youth with CP: “in my practice alone, I am constantly being creative and trying to make [rehabilitation exercise] a game. Not necessarily a virtual reality game, but in a game in general to … mask the idea that they’re doing these … sets of exercises but trying to make it fun, and that helps a lot.” This fact that gamification is already a common tactic in rehabilitation for youth with CP suggests that a video game such as Bootle Rumble would be a welcome addition to a physiotherapist’s toolset.

The PTA remarked that at-home rehabilitation is harder to observe and regulate than in-clinic rehabilitation, as regulation of at-home rehabilitation requires motivation and self-advocation from youth with CP and their families: “It could be like, ‘okay you have to set an appointment, and you’ll see your PT in the next 6 months.’ Right? So what’s happening in those 6 months? Do they forget to bring up the fact that they’ve done the whole program? Does the PT remember? Does it even matter to anybody in the end? … It’s the onus and the autonomy of … the client and the family to bring it up”. Perhaps future iterations of Bootle Rumble could include
the ability for physiotherapists to check up on their clients’ adherence to, and quality of, at-home rehabilitation exercise, reducing the need for self-advocacy for youth with CP and their families.

In conclusion, interviews with the participating PTA and parent/guardians of participating youth with CP yielded the following information: none of our participating youth with CP perform at-home rehabilitation as often as our PTA would recommend; there are resources available for youth with CP in Toronto with regard to in-clinic rehabilitation; different children with CP have different needs with regards to in-clinic rehabilitation, and therefore require different resources; physiotherapists often prescribe at-home rehabilitation exercises to youth with CP for a variety of reasons (following surgery, to extend range of movement, to maintain fitness, for functional reasons, or as an adjunct to in-clinic rehabilitation); gamification is informally used in in-clinic rehabilitation, though not necessarily through a video game such as Bootle Rumble; and at-home rehabilitation is harder to observe and regulate than in-clinic rehabilitation. All of these observations suggest that an interactive rehabilitation exercise game such as Bootle Rumble could be beneficial for youth with CP who are prescribed at-home rehab.

6.3 Quality of Exercise

In this section we examine our results exploring players’ quality of exercise while playing Bootle Rumble, and the effect (if any) that the form-tracking mechanic had on participants’ quality of exercise.

On the custom physiotherapist questionnaire, the PTA answered that she had no need to intervene due to dangerous form in any condition or session, suggesting that the risk of injury while playing Bootle Rumble was found to be low whether or not the form-tracking mechanic was enabled. The PTA also responded that participants’ quality of exercise during gameplay was “good” in the first session, and “very good” in the second session, suggesting that quality of exercise is high during play of Bootle Rumble regardless of the presence of the form-tracking mechanic. The PTA also stated that she observed improved quality of exercise in the
experimental condition (where form-tracking was enabled) in both study sessions; in the first session (with participants Tiger and Bear) the quality of exercise observed in the experimental condition was “better” than the control, and in the second session (with Lynx and his typically-developing siblings) it was “much better”. In the semi-structured interview, the participating PTA confirmed that quality of exercise improved when the form-tracking mechanic was enabled: “For our specific session right now … quality [of exercise] improved [when form-tracking was enabled] … [and also] last session … for the most part, yes. When concentration was up … Absolutely.” This perceived improvement suggests that the form-tracking mechanic in Bootle Rumble does reduce the predicted risk of injury and increase the predicted benefit of exercise.

However, the PTA’s questionnaire responses contradict the form scores she recorded during gameplay. For two of the three participants (Tiger and Lynx), there was very little difference in average form score across conditions, while one participant (Bear) showed a decrease in average form score from 2.31 in the control condition to 1.88 in the experimental condition. This contradiction could be due to the PTA evaluating form scores with greater scrutiny as each session progressed. It is also possible that the inclusion of the form-tracking mechanic does generally reduce the quality of exercise of players, but the PTA was not consciously aware of the reduction. In any case, while the PTA’s interview and questionnaire responses are promising with regard to quality of exercise, further research is required to quantitatively prove whether the presence of form scoring improves players’ quality of exercise.

The participants’ responses to the OMNI Perceived Exertion Scale show that, in general, participants perceived greater exertion in the experimental condition than the control condition. This could be due to participants becoming fatigued over the course of their session, since participants always played the experimental condition after the control condition. It is also possible that the experimental condition motivates greater exertion than the control condition. Further research is required to determine if this is the case.
In summary, the PTA’s responses to the PTA questionnaires and semi-structured interview indicate that quality of exercise during play of Bootle Rumble is high, and that the introduction of the form-tracking mechanic in the experimental condition resulted in improved quality of exercise compared to the control condition. However, the form scores recorded by the PTA contradict her observations, and indicate that the form-tracking mechanic may in fact have little, or even negative, impact on quality of exercise. Participants’ responses to the OMNI Perceived Exertion Scale show that participants perceived greater exertion in the experimental condition than the control condition, though this could be due to fatigue because of the order of conditions. Further research is required to determine whether Bootle Rumble’s form-tracking mechanic incentivizes high quality of exercise and/or greater exertion, though initial results are promising.

### 6.4 Player Enjoyment

In this section we evaluate participants’ enjoyment while playing Bootle Rumble using their SEAS Questionnaire responses, and their semi-structured interview responses.

In evaluating RQ2, the most relevant SEAS subscale is Psychological Engagement, as it contains the following questions: “I felt I was interested”, “I felt I was having fun”, “I felt excited”, and “I felt in a good mood”. Responses to the Psychological Engagement Subscale were unanimously positive, with eight of twelve responses being strongly positive. With regards to RQ2, this result suggests that players did in fact enjoy playing Bootle Rumble in general. This indicates that Bootle Rumble has potential to enhance the enjoyment of at-home rehabilitation exercise for youth with CP.

However, participants’ semi-structured interview responses were not generally as positive as their Psychological Engagement responses might lead one to believe. When asked “Would you play [Bootle Rumble] at home,” two of three participants (Bear and Tiger) responded neutrally/negatively, while only one participant (Lynx) responded positively. Tiger responded
that he would “not really” want to play Bootle Rumble at home as it “isn’t really [his] style” and suggested “[making] it more sporty” or “a Mario version”. Twelve-year-old Tiger is the oldest participant, so it is possible that he did not identify with the cartoonish style of Bootle Rumble. However, nine-year-old Bear also stated that Bootle Rumble “doesn’t seem that appealing, um, looking to my other games that I have.” Both participants seem to compare Bootle Rumble to popular industry video games, advocating for changes to make Bootle Rumble more similar to games they already play.

Positive responses to the Choice and Control subscale reflect that the participants felt that they had agency during gameplay. For example, all three participants responded positively to the question, “I felt that I could choose what to do for the most part”, even though they had no agency over the exercises they were performing. This suggests that Bootle Rumble is able to preserve player agency even during the rumble phase, where it could be unsafe for players to make choices about their exercise regimen.

While SEAS responses suggest that players felt that they were in control while playing Bootle Rumble, Bear advocated for even further control with respect to strategy. When asked what changes could be made to make him more likely to play Bootle Rumble at home, Bear said, “More strategy. Like different attacks… [you] can encounter characters, can do more damage on different characters, and … some attacks would be weaker, and some characters have a set level of attacks that they can do”. Bear’s suggestion to add deeper strategy and gameplay should be considered, especially in conjunction with participants’ inclination to compare Bootle Rumble to popular industry games. By intent, Bootle Rumble’s strategy is simple when compared to popular turn-based strategy games such as the Pokémon [12] franchise. Perhaps in the future, like these popular titles, Bootle Rumble’s strategy should be as deep as the player wants it to be. Players like Bear would be able to think deeply about their strategic choices and have fun. Conversely, players like Tiger would be able to disregard deeper strategy and still have fun with the exercise-
based elements of the game. Perhaps the best way for Bootle Rumble to compete with popular strategy games is to mimic them as closely as possible, rather than to simplify them.

Positive responses to the SEAS Social Belonging subscale suggest that players had positive interpersonal experiences, even though Bootle Rumble is a competitive multiplayer game. The mostly-positive responses on the Meaningful Interactions subscale show that players had positive experiences sharing thoughts and feelings during gameplay, which reinforces that players interacted in positive ways despite the competitive nature of the game.

Finally, neutral scores on the Personal Growth subscale show that players had neutral experiences relating to personal competence. Bootle Rumble is not focused on incentivizing personal growth for players, and in any case one would not expect a high degree of personal growth from a single play session of Bootle Rumble. In retrospect we could reasonably have omitted the Personal Growth subscale from the SEAS questionnaire during our pilot study.

In summary, while their SEAS responses reflect positively on the enjoyability of Bootle Rumble, two of the three participants stated they would be unlikely to play the game at home. Furthermore, the novelty effect may have played a role in the overwhelming positivity of participants’ SEAS responses. Nevertheless, highly positive responses to the SEAS subscales of Psychological Engagement, Choice and Control, Social Belonging, and Meaningful Interactions show promise for Bootle Rumble as an enjoyable adjunct to at-home rehabilitation exercise. In order to compete against other games and encourage long-term play, future work should expand the strategic elements of Bootle Rumble such that it is comparable to popular contemporary turn-based strategy games. Further research should examine the enjoyability of playing Bootle Rumble regularly over a longer period of time.

6.5 Design Decisions

In this section we evaluate elements of Bootle Rumble’s design with respect to our results.

6.5.1 Promoting High-Quality Exercise
Our primary goal in designing Bootle Rumble was ensuring that players perform high-quality exercise during play using the form-tracking game mechanic. As mentioned in section 3.1, Bootle Rumble attempts to incentivize high-quality exercise through (1) the form-tracking mechanic, where players receive real-time feedback on quality of exercise through visual effects, voiceover audio, and strategic benefits, (2) the Botley animation mechanic in which the Botley character performs exercises alongside the player, and (3) the webcam mirror which allows players to observe their own form during play. In our pilot study, the form-tracking mechanic was disabled in the control condition, and enabled in the experimental condition. To evaluate the effectiveness of Bootle Rumble and its form-tracking mechanic in promoting high-quality exercise, we (1) examine the PTA’s responses to the PTA questionnaires and semi-structured interview, (2) compare the form scores provided by the PTA during the control and experimental conditions to see if quality of exercise improved in the presence of the form-tracking mechanic, and (3) evaluate participants’ semi-structured interview responses to determine if the Botley animation and webcam mirror mechanics were helpful for players.

6.5.1.1 Form-tracking

As described in section 6.3, in the PTA questionnaire and semi-structured interview, the participating PTA reported that quality of exercise during play of Bootle Rumble was high in general and improved when the form-tracking mechanic was enabled. However, the form scores recorded during gameplay suggest that the form-tracking mechanic has little effect on quality of exercise, and could even have a negative effect. Further research is required to quantitatively determine what effect form-tracking has on quality of exercise, if any. However, the PTA’s qualitative comments show promise for the form-tracking mechanic.

6.5.1.2 Botley Animations

During the rumble phase, Bootle Rumble displays an animation of a character named Botley performing the same exercise as the player (as shown in Figure 3-3). During their semi-
structured interviews, we asked participants whether or not they found this game mechanic helpful. Two of our three participants (Bear and Lynx) responded that they found Botley helpful, while one participant (Tiger) responded that he did not. Bear’s response, “I found it useful, especially if you didn’t have someone to help you,” reflects positively on the Botley mechanic, since Bootle Rumble would ideally be deployed in the homes of youth with CP where a physiotherapist is not present. However, this necessitates stronger quality assurance with regard to the quality of exercise portrayed in Botley’s animations as it would be potentially dangerous for Botley to set a bad example. Furthermore, Bear’s statement, “It might not be the best way because you can’t really see sometimes,” refers to the fact that Botley’s animation was partially blocked by the text describing the exercise. Tiger’s negative response with regards to Botley is possibly due to the fact that he was the most sportive/active participant in the study, and was already comfortable with his rehabilitation exercises without the help of Botley. However, his recommendation to “hide [Botley] and show [him] sometimes” suggests that he may have found Botley helpful for exercises he was less familiar with.

6.5.1.3 Webcam Mirror

The rumble phase also includes a webcam mirror (as shown in Figure 3-5). During the semi-structured interviews, we asked participants whether they found the webcam mirror helpful, to which all participants responded positively. Participants’ responses all indicated that they understood that the mirror helped them correct their form during gameplay, as intended. However, we do not know the extent to which participants’ quality of exercise was affected by the Botley animation or webcam mirror mechanics. Future work could examine these mechanics more closely with similar methodology to our pilot study, which focused on the form-tracking mechanic specifically.

In conclusion, further research is required to determine whether Bootle Rumble does effectively incentivize high-quality exercise, and to what extent the form-tracking mechanic plays
a role. The observations presented by the participating PTA are promising in this regard, but the form scores gathered during the study do not corroborate those observations. Results are also promising with regards to the Botley animation and webcam mirror mechanics, but to date we have no quantitative data to claim that the presence of those mechanics had any effect on quality of exercise.

6.5.2 Balancing for Different Ability Levels

Bootle Rumble was designed to be balanced for effort rather than ability. That is, the end result of a game of Bootle Rumble should not be dependent on the ability level of the players, but should instead depend on their in-game choices during the strategy phase, and how much effort they put into their exercise during the rumble phase. As described in section 3.2, we attempted to balance Bootle Rumble for effort by (1) using custom exercise regimens for each individual player, and (2) providing form feedback with knowledge of each individual’s ability level. In this section we evaluate the effectiveness of these design decisions by examining the participants’ responses to semi-structured interview questions regarding fairness.

During the semi-structured interviews, we asked participants “How would you describe the game’s fairness?” In response, all three participants responded that they felt the game was fair. However, one participant (Bear) stated that he thought the control condition was more fair than the experimental condition: “I think it was pretty fair. Especially for the the [control version]… For the [experimental version], it mostly comes down to the person you’re [playing] against”. Bear felt that players’ ability levels play a role in who wins a game of Bootle Rumble when the form-tracking mechanic is enabled, but don’t play a role when form-tracking is disabled. This result has implications for our inclusion of form-tracking in Bootle Rumble. Perhaps there is more we can do to balance for effort in Bootle Rumble’s design. Perhaps if Bootle Rumble were designed as a cooperative multiplayer game rather than a competitive
multiplayer game, differences in ability level during gameplay would not be as important or apparent.

However, it is worth mentioning that during the second session, where Lynx played against his typically-developing siblings, Lynx responded that he thought the game was fair despite the difference in ability level between himself and his opponents. Furthermore, during this session, both games ended in ties. This indicates that the game is at least somewhat successful at balancing for effort.

In conclusion, our results suggest that Bootle Rumble is successful at balancing for effort via the following design decisions: customizing each player’s exercise regimen based on their specific abilities and providing form feedback with relative to each individual’s ability level. Bear’s perception that form-tracking reduces the fairness of Bootle Rumble is not without merit, and could be further explored in future work. However, there is a difference between fairness and the perception of fairness, and the ability of Bootle Rumble to facilitate competition between typically and non-typically-developing people (as observed when Lynx played against his typically-developing siblings) suggests that Bootle Rumble succeeds at balancing for effort.

6.5.3 Considering the Needs of Youth with Cerebral Palsy

In section 3.3 we described four game design decisions that we made in order to ensure that Bootle Rumble was playable by youth with cerebral palsy: (1) turn-based gameplay, to eliminate the need for precise timing of input, (2) a control scheme with redundant button mappings to aid accessibility, (3) a sparse visual layout to reduce the need for complex visual-spatial processing, and (4) reinforcement of the game state using visual, text, and audio cues. In this section we evaluate the effectiveness of these choices at making Bootle Rumble accessible for youth with CP, by examining participants’ responses during their semi-structured interviews.

During their semi-structured interviews, participants were asked “Did you find the game’s controls easy to use?”, to which all three participants responded “yes”. This is evidence
that our control scheme is accessible to these youth with CP, but our other three design decisions relating to accessibility may have played a role as well. Furthermore, because all three participants had experience using handheld controllers, it remains unclear whether the accessibility of Bootle Rumble’s control scheme extends to all youth with cerebral palsy. However, our initial results indicate that our choice to use a redundant control scheme on a traditional handheld controller was successful in aiding accessibility for youth with CP. Future research is necessary to determine the extent to which our other design decisions aid accessibility: turn-based gameplay to eliminate time-sensitive inputs, a sparse visual layout to reduce cognitive load, and reinforcement of the game state using visual, text, and audio cues.

6.5.4 Designing for Fun

The final consideration for Bootle Rumble’s design, outlined in section 3.4, relates to ensuring that the game remains fun while balancing the three previous design constraints. This consideration resulted in two design decisions: (1) offering the opportunity for agency during gameplay (during the strategy phase), and (2) using the illusion of randomness when agency is not possible (during the rumble phase). Both of these design decisions intend to maximize feelings of agency during play in order to increase feelings of engagement. In this section we evaluate the effectiveness of Bootle Rumble’s design in fulfilling that intention by examining the participants’ responses in the SEAS questionnaire subscales of Choice and Control (CC) and Psychological Engagement (PE).

The SEAS questionnaire’s Choice and Control (CC) subscale measures participants’ feelings of agency. Participants responded positively to questions belonging to this subscale, with an average score of 1.5. This demonstrates that players felt they had the ability to make meaningful choices during gameplay. This result is intriguing as players were unable to make any choices during the rumble phase—all participants’ exercise regimens were prescribed prior to their session and were presented in a random order during gameplay—but participants were left
with strong feelings of agency despite this. This suggests that players are willing to participate in a rigid exercise regimen during gameplay as long as the game offers enough strategic choices.

The SEAS questionnaire’s Psychological Engagement (PE) subscale measures participants’ engagement. Participants responded positively to questions belonging to this subscale, with an average PE score of 1.4, indicating that participants were highly engaged while playing Bootle Rumble. This result shows great promise because it suggests that we successfully balanced the three previously described design constraints without sacrificing the fun of the game. Furthermore, in conjunction with the average CC score of 1.5, positive PE scores show that, while playing Bootle Rumble, players not only feel agency in a setting where they have no control over their exercise regimen but are highly engaged by the experience as well.

In summary, we find that based on participants’ SEAS responses in the subscales of Choice and Control (CC) and Psychological Engagement (PE), participants felt that they had agency, and were highly engaged while playing Bootle Rumble. This is a promising result, especially because players had no control over which exercises they were performing during the rumble phase. Future research could measure SEAS responses of youth with CP after participating in traditional non-gamified rehabilitation exercise to determine how feelings of agency change when Bootle Rumble is introduced. However, we can claim with some confidence that the following design decisions succeeded in providing players with feelings of agency and engagement while playing Bootle Rumble: providing opportunities for agency when it is safe to do so (in the strategy phase), and using the illusion of randomness in moments where it is not safe to provide agency (in the rumble phase).

6.6 Conclusion

In this chapter, we have synthesized our results to explore our research questions and learn more about the effectiveness of our design decisions for Bootle Rumble. We have characterized our three participants to provide further context for their responses. We have
examined interviews to learn more about rehabilitation for youth with CP from the perspective of a PTA and the parent/guardians of youth with CP. With regards to RQ1, we have found that while our PTA’s qualitative assessments of quality of exercise suggest that Bootle Rumble (and its form-tracking mechanic) promote high-quality rehabilitation exercise, further research is needed to quantitatively substantiate those assessments. Concerning RQ2, we found that although participants responded positively to the SEAS questionnaire, two of three were not enthusiastic about playing Bootle Rumble at home due to competition from popular industry strategy games.

We have evaluated the design decisions that arose from our four design constraints:

1. **Promoting High-Quality Exercise:** Qualitative responses from the PTA suggest that form-tracking is beneficial to quality of exercise. Form scores recorded by the PTA suggest that form-tracking has a neutral, or perhaps negative, effect on quality of exercise. Two of three participants found Botley’s animations useful throughout gameplay, and one participant only found them useful for exercises he was less familiar with. All three participants found the webcam mirror useful for self-correction.

2. **Balancing for Different Ability Levels:** One participant felt that form-tracking caused gameplay to be more reliant on ability level. However, all three participants reported that the game was fair, and Bootle Rumble was able to facilitate competition between typically and non-typically-developing players. This was accomplished by (a) using custom individualized exercise regimens and (b) providing form-scores with an understanding of each player’s individual ability level.

3. **Considering the Needs of Youth with Cerebral Palsy:** All three participants reported that Bootle Rumble’s control scheme (using a traditional handheld controller with redundant button mappings) was easy to use. We have no evidence to confirm
that our other design decisions intended to promote accessibility were effective, but they may have played a role in the usability of Bootle Rumble’s control scheme.

(4) **Designing for Fun:** Participant responded unanimously positively to the SEAS subscales of Choice and Control (CC) and Psychological Engagement (PE). This suggests they felt they had agency and were engaged despite having no control over the exercises presented to them in the rumble phase. This suggests that Bootle Rumble improves enjoyment of rehabilitation exercise by (a) providing agency when it is safe to do so (i.e. in the strategy phase) and (b) using the illusion of randomness when it is not safe to provide agency (i.e. in the rumble phase).

The results gathered in our pilot study show that Bootle Rumble has potential as a supplement to at-home rehabilitation exercise which increases enjoyment without sacrificing quality of exercise. Furthermore, the design decisions present in Bootle Rumble are generalizable in the domain of rehabilitation exercise games for youth with CP and could be beneficial to future researchers and developers intending to create games for similar purposes.
Chapter 7

Conclusion

In this thesis, we have explored the domain of rehabilitation for youth with cerebral palsy and the challenges faced with regards to adherence and enjoyment of rehabilitation exercise. As a potential solution to the adherence problem, we present a prototype exergame called Bootle Rumble, which intends to motivate high-quality at-home rehabilitation exercise for youth with cerebral palsy without sacrificing enjoyability.

Bootle Rumble balances four separate constraints in its design: (1) the game must not only motivate exercise, but maximize the intended benefits of the exercise and minimize the risk of injury; (2) it must be accessible to youth with cerebral palsy, such that they are able to understand the gameplay and provide input without frustration; (3) it must be balanced for effort rather than ability, such that two players with different ability levels can play together; (4) it must address all previous constraints without sacrificing the fun of the game. These four constraints led to many design decisions whose effectiveness were not yet proven.

To evaluate the effectiveness of Bootle Rumble’s design, we completed a pilot study involving three youths with cerebral palsy, their parent/guardians, and a physiotherapy assistant (PTA) who works with youth with cerebral palsy. Our pilot study aimed to explore three research questions: (RQ1) Does the presence of the form-tracking mechanic in Bootle Rumble improve players’ quality of exercise? (RQ2) Do participants enjoy playing Bootle Rumble? (RQ3) How effective are Bootle Rumble’s design decisions with respect to quality of exercise, accessibility, game balance, and fun? While we were not able to draw quantitative conclusions from our pilot study due to a small sample size, initial results show promise for future iterations of Bootle Rumble as an enjoyable supplement to at-home rehabilitation exercise.
We learned about the attitudes towards rehabilitation for our participating youth with CP from interviews with their parent/guardians and a PTA who works with the population of youth with CP. We found that the PTA already informally uses gamification to increase the enjoyability of rehabilitation exercise. We also found that none of our participating youth with CP meet the participating PTA’s standard of at-home rehabilitation (30 minutes per day, every day). Two parent/guardians cited a lack of motivation as a contributing factor to their child not meeting their at-home rehabilitation goals. Participant Bear’s parent/guardian even mentioned that Bootle Rumble acted as an analogue to the reward-based motivation that they provide at home for their child. These remarks all point towards gamification of rehabilitation (through Bootle Rehab or a similar system) as beneficial to enjoyment of, and therefore, adherence to rehabilitation exercise for youth with cerebral palsy.

With regards to RQ1, our pilot study yielded conflicting results. We found some qualitative evidence that the form-tracking mechanic—where players’ quality of exercise influences the effectiveness of their strategic choices during play—has a positive effect on the quality of exercise of players, as reported by the PTA during her semi-structured interview. She also noted that participants were aware that quality of exercise was integral to gameplay when form-tracking was enabled. Form scores recorded by the PTA, however, showed inconclusive effect of form-tracking on quality of exercise, with effects ranging from mildly positive to negative. There are several possible explanations for this result, which we discuss in Chapter 6. Further research is required to determine the actual effect of form-tracking on quality of exercise. If form-tracking can be quantitatively proven to have a positive effect on quality of exercise, future work could automate the form-tracking process to facilitate at-home play of Bootle Rumble.

Concerning RQ2, participants’ responses to the SEAS questionnaire indicated that playing Bootle Rumble was a highly positive experience for them. Positive responses to the
Psychological Engagement subscale show that players felt the game was fun and exciting, which suggests that Bootle Rumble does have potential to be an enjoyable adjunct to rehabilitation exercise for youth with cerebral palsy. However, in their semi-structured interviews, only one participant (Lynx) responded that he would play Bootle Rumble at home. Neutral/negative responses on this subject from the other two participants (Tiger and Lynx) indicate that further work must be done to make Bootle Rumble more comparable to current popular games. It may not be possible for Bootle Rumble to ever compete with games like the Pokémon handheld games [12], but future work should aim to deepen the strategy of Bootle Rumble in an attempt to do so.

Future research should also explore the enjoyability of Bootle Rumble over multiple play sessions, and with a larger participant pool.

RQ3 relates to evaluating the Bootle Rumble’s design decisions. While we cannot make any claims regarding the effectiveness of several of the mechanics present in Bootle Rumble, we have some supporting evidence concerning the following design decisions:

- *Devise a way for the quality of players’ exercise to influence their gameplay (form-tracking):* In Bootle Rumble, an observer manually scores the form of players while they exercise. The scores provided by the observer influence the effectiveness of players’ in-game actions. The participating PTA responded that this mechanic improved players’ quality of exercise. Furthermore, participants saw the value of this mechanic in motivating high-quality exercise, and in one case it greatly improved a participant’s enjoyment (Lynx). Form scores recorded by the PTA did not show a clear improvement in quality of exercise.

- *Allow players to monitor their form by providing a mirror image during exercise:* In Bootle Rumble, a mirror image is shown during the rumble phase while players exercise. All three participants responded that this helped them self-correct their form.
• **Provide animations of exercises with which players can compare their own form:** In Bootle Rumble, a character named Botley exercises along with players. Two of three players found this generally valuable as they could compare their form to Botley’s. The other participant (Tiger) only found this mechanic useful sometimes (i.e. for exercise with which he was less familiar).

• **Personalize the exercise regimens of players, and grade their form based on their unique ability level:** In both study sessions, the participants playing Bootle Rumble together had different ability levels. In one session, Bootle Rumble facilitated play between a player with motor function classified at GMFCS III and a typically-developing player. This was accomplished by customizing exercise regimens and form-scoring according to the abilities of each individual player. However, there is room for subjectivity on the part of the observer in the application of the rubric.

• **Implement a simple control scheme with redundant button mappings for accessibility:** In Bootle Rumble, we used a control scheme using a traditional Logitech F710 wireless gamepad controller, where all front-facing buttons (A,B,X,Y) were used for selection, the bumpers (RB and LB) were used to cancel selections, and the left stick was used to navigate. All three players (who were familiar with gaming and controllers) found this control scheme easy to use.

• **Provide opportunities for agency when players are not exercising, and utilize the illusion of randomness when players are exercising:** Each turn in Bootle Rumble is separated into two phases: the strategy phase where players make strategic choices, and the rumble phase where players exercise but cannot make any in-game choices. All three players responded to the SEAS questionnaire with highly positive responses to Psychological Engagement and Choice and Control, suggesting that
players were highly engaged by gameplay and felt that they were in control, despite having no control over the exercises being prescribed to them.

The game design decisions listed above could be of value to future developers intending to gamify rehabilitation exercise for youth with cerebral palsy. However, it must be noted that the evidence supporting these game mechanics came from a pilot study with only three participating youth with cerebral palsy. In order to further reinforce the validity of these design decisions and evaluate the effectiveness of any other of Bootle Rumble’s design decisions, future studies should be performed with a larger participant pool. These studies could also involve multiple play sessions per participant to determine how players’ enjoyment changes as they become more familiar with the game.
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Appendix A
OMNI Perceived Exertion Scale

Participant Post-Condition OMNI Scale
Session: ___

Condition 1
Circle the number that matches your effort.

![OMNI Perceived Exertion Scale for Resistance Exercise](image)

Condition 2
Circle the number that matches your effort.

![OMNI Perceived Exertion Scale for Resistance Exercise](image)
Appendix B
SEAS Questionnaire & Score Sheet

Page 1

Self-reported Experiences of Activity Settings
(Picture Communication Symbols® version)

You need to do an activity for at least 15 minutes. You could be at home, outside your home or in an organized activity setting.

There are no right or wrong answers. Answer as truthfully as you can.

Your answers to questions are about your experiences when you did that activity and are not a reflection on you.

It is ok if you don’t want to answer a question.

Page 2
**Instructions:**

Tell us how you felt while doing the activity.

Answer the question by choosing the side of the scale that shows how you felt.

Tell us if you agree a little, agree, or strongly agree with the statement.

**Example 1:**

If you felt very happy while doing the activity, choose:

- ++ ++ 0 + +

happy 0 6 0 6 0 6 0 6 sad n/a
A. What kind of OVERALL mood were you in when you were doing the activity? I felt ...

I felt ...

- in a good mood
- in a bad mood
- exited
- bored

B. For the most part while doing the activity I felt...

I felt ...

- I was having fun
- I wasn’t having fun
- I was in control (i.e. made decisions, in charge)
- I lacked control (i.e. let others decide, not in charge)
- I was interested
- I was disinterested
- I was challenged
- I was unchallenged
C. With respect to myself, I felt...

I felt ...
- Strongly Agree
- Agree
- Agree a little
- Neither
- Disagree a little
- Disagree
- Strongly Disagree

I discovered things about myself

I didn't discover things about myself

I talked about my thoughts and feelings

I didn't talk about my thoughts and feelings

D. With respect to choices and opportunities I felt...

I felt ...
- Strongly Agree
- Agree
- Agree a little
- Neither
- Disagree a little
- Disagree
- Strongly Disagree

I could choose what to do for the most part

I couldn't choose what to do

I was free of pressure

I was pressured to do something I didn't want to do

I had a say in things

I didn't have a say in things
E. With respect to doing the activity I felt...

**I felt** ...

- I tried something new
  - + + + 0 + +
  - I didn't try anything new
- I learned a new skill
  - + + + 0 + +
  - I didn't learn a new skill
- I became better at something
  - + + + 0 + +
  - I didn't become better at anything

F. With respect to people I felt...

**I felt** ...

- I got along with others
  - + + + 0 + +
  - I didn't get along with others
- I belonged (i.e., I was part of the group)
  - + + + 0 + +
  - I didn't belong (i.e., I felt left out)
- I was valued by others (i.e., appreciated, respected)
  - + + + 0 + +
  - I wasn't valued by others (i.e., not appreciated)
G. Sometimes we have really cool experiences that are out of the ordinary. While doing the activity I felt ...

I felt ...

- I shared something special
- I didn't share something special

- I grew or changed
- I didn't grow or change

I was supported and encouraged by others
I wasn't supported and encouraged by others
I had good conversations with others
I didn't have good conversations with others
I shared ideas about things important to me
I didn't share ideas about things important to me
H.

Did you feel any different after doing this activity?

Please explain:

Thank you for answering our questions!

Page 16

Background Information:
This following section may be completed by parents or caregivers after observing the youth take part in a recreational or leisure activity of their choice for at least 15 minutes.

A. Date youth completed the activity: __________/__________/__________ (Day/Month/Year)

B. What activity did the youth do? (Example: a sports, art class etc.)

C. Is the activity:

- a formal activity (i.e., structured or course-based)?
- an informal activity?

D. Where did the youth do that activity? (Example: at the kitchen table in my house, at the YMCA)

E. Who did the activity with the youth?

- Parents
- Siblings
- Other Relatives
- Friends
- Other
- No One

F. Who else was there besides those who did the activity?

(Example: my mother, other children, an instructor etc.)

G. What time of day was the activity started? ____________ o am o pm

H. Is this the first time the youth has been in this activity setting?

- Yes
- No

I. Please circle the number on a scale from 1 (Not at All) to 7 (To a Very Great Extent) that indicates how familiar the youth was with:

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J. Did the youth have any help filling out this questionnaire?

- Yes
- No

If Yes, who helped?

- Parent
- Sibling
- Friend
- Service Provider
- Other

If Yes, how did they help?

- The youth provided the answers and someone else filled them in.
- The youth had help with figuring out some of the answers.
- The youth had help reading the questions and/or explaining words.
- The youth had help with figuring out most of the answers.
- Other (please specify)

Please feel free to tell us anything else about your child’s experiences in different activity settings that you would like us to know.

Thank you for answering our questions!

Score Sheet

© King, Batorowicz, Rigby, Petrenchik, Gibson & McMahon-Klein (2010)

This work was supported by the Canadian Institutes for Health Research [TWC-95045].

Illustrated by Apati Raczynska (www.apatki.art.pl/illustracji)
# Score Sheet (cont’d)

**Summary Score Sheet**

**SEAS Scale Scores**

Directions: Copy each item response from the SEAS questionnaire into the corresponding coloured box.

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### A NUMBER OF ITEMS

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<td>Yes</td>
<td>No</td>
<td>Yes</td>
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</table>

### B Do you have responses for at least this many items?

(If Yes, then proceed. If No, DO NOT proceed.)

<table>
<thead>
<tr>
<th></th>
<th>4</th>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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</table>

### C TOTAL

(Add the values in each column to get a sum.)

### D SEAS SCALE SCORE

(Divide row C-TOTAL by row A-NUMBER OF ITEMS. Use 2 decimal places.)

### OVERALL TOTAL (OT)

Add values across row C.

### TOTAL ITEMS (TI)

Add values across row A.

### AVERAGE RESPONSE (AR)

$$ \frac{OT}{TI} = AR $$
Appendix C
Custom Questionnaire for Participating PTA

Therapist Post-Session Questionnaire
1. What was the quality of the participants’ exercise? (Circle your response)
   - Very Poor
   - Poor
   - Neutral
   - Good
   - Very Good

Can you elaborate on your answer? (Use the space provided)

2. How did the quality of exercise in the experimental condition (with form tracking) compare to that of the control condition (without form tracking)?
   - Much Worse
   - Worse
   - Same
   - Better
   - Much Better

Can you elaborate on your answer? (Use the space provided)

Did you have to intervene at any point due to dangerous form? If so, in which conditions did you have to intervene? How many times? (Use the space provided)
Appendix D

Semi-Structured Interview Script for Participating Youth with CP

- Do you agree with the statement “I would play this game at home.”?
  o Likert Scale → Strongly disagree, disagree, neutral, agree, strongly agree
  o If agree or neutral, why?
  o If disagree, what elements of the game do you think we should change to make you want to play it at home? What elements of the game make you not want to play it at home?
- You played two different versions of Bootle Rumble today. In the first version, the strength of your attacks was random. In the second version, your exercise quality changed the effectiveness of your attacks. Which version did you prefer? Why?
  o Likert Scale → First version much better, first version a little better, same, second version a little better, second version much better
- How would you describe the game’s fairness?
  o Likert Scale → Very unfair, unfair, neutral, fair, very fair
  o If fair, why?
  o If unfair or neutral, how could the game be made more fair?
- How would you describe the game’s difficulty?
  o Likert Scale → Very easy, easy, neutral, hard, very hard
  o If fair, why?
  o If unfair or neutral, how could the game be made more fair?
- During the exercise phase of the game, we showed you a video of yourself performing the exercises. What did you like about this? What didn’t you like?
- While performing your exercises, the robot character named Botley did the exercise along with you. Did you find this helpful? Why or why not?
- Did you find the game’s controls easy to use? Why or why not?
Appendix E

Semi-Structured Interview Script for Participating Parent/Guardians

- Does your child come to the hospital, or any other clinic, to do rehabilitation exercises? How frequently?
- Has your child ever been assigned rehabilitation exercises to perform at home?
- If your child has been prescribed rehab exercises for home,
  o Was the person who assigned these exercises a therapist? (If no, then who?)
  o What were the circumstances of these exercises (e.g. following surgery, to extend range of movement, to maintain fitness, etc...)?
  o How often does your child perform these exercises?
  o Does anything get in the way of your child performing their at-home exercises?
  o If they don’t do them as often as prescribed… What might help your child to perform their at-home exercises more frequently?
  o Does your child enjoy performing at-home exercises?
Appendix F

Semi-Structured Interview Script for Participating PTA

- Is physiotherapy and/or occupational therapy important for children and youth with CP? Why or why not?
  - Can you briefly reflect on the importance of physio- and occupational therapy for children and youth with CP? Are there particular situations where they are most important?
- What resources are available for children to come into the hospital to perform rehab in the presence of a physiotherapist?
- How often do you prescribe or recommend rehabilitation exercises for kids with CP to perform at home?
  - What do you view as the role of therapy at home? Is this an adjunct to therapy in the clinic, or something that can be done standalone? Is home therapy something you use of necessity due to lack of resources to see everyone in clinic?
- If you do prescribe rehab exercises:
  - How frequently do you ask children to perform the exercises you prescribe?
  - What does a typical exercise prescription look like?
- Are there sufficient resources to follow up with these kids to learn whether they are performing their exercises, or if the exercises are effective?
- Do you think the children with CP enjoy doing their rehabilitation exercises?
  - Do you think incorporating these exercises into a game such as Bootle Rehab would make them enjoy it more?
Appendix G
Form-Scoring Rubrics

General Scoring Key:
0 – does not initiate movement, or completes than< 25% of the expected movement
1 – Completes 25% of the expected movement, movement controlled for <50% of task (includes holding position for specified time), or uses significant compensations
2- Completes 26-90% of the expected movement, movement controlled for >50% of task (includes holding position for specified time), mild-moderate compensation used
3 – Completes 90-100% of the expected movement, movement controlled throughout (including holding the position for the specified time), very mild to no movement compensations used

Ankle Dorsiflexion:
Purpose: To strengthen ankle dorsiflexors (muscles on the front of lower leg used to lift the foot up)
0 – toe extension only
1 – Forefoot raised from floor slightly (<25% of expected movement), may or may not control lowering the foot back down.
2 – Forefoot raised from floor 26-90% of the expected movement, able to somewhat control lowering the foot to the floor
3 – Forefoot raised from the floor 90-100% of the expected movement, foot lowered to the floor with control

Heel Raises:
Purpose: To strength the calf muscles at the back of the lower leg
0 – heel remains on floor or < 1cm
1 – heel is raised off the floor 25% of expected movement (~1 cm), the knee may flex as compensatory movement, may or may not control lowering heel to floor.
2 – heel is raised off the floor 26-90% of expected movement, ankle in plantarflexion (if able to visualize), knee may flex moderately ~30 degrees, able to somewhat control lowering heel to floor
3 – heel is raised off the floor 90-100% of expected movement, ankle in plantarflexion (if able to visualize), knee may be mildly flexed (<10 degrees), controls heel lowering to floor
**Hip Abduction:**

Purpose to strengthen the muscles on the side of the hip that help provide pelvic stability

i) Supine/lying on back:

0 – legs do not move apart, or hip flexion only

1 – abducts hips 25% of the expected movement, may compensate with associated hip flexion

2 – abducts hips 26-90% of the expected movement, may compensate with moderate associated hip flexion

3 – abducts hips 90-100% of the expected movement, mild associated hip flexion (i.e. legs remain in contact with bed throughout movement)

ii) Hip abduction in Standing:

0 – unable to abduct the hips or completes <25% of the movement, may side flex trunk to compensate

1 – abducts hip 25% of the expected movement, may side flex trunk or flex at hip and knee to compensate, may or may not control lowering of leg

2 – abducts hip 26-90% if the expected movement, mild compensations of trunk, hip and knee permitted, able to somewhat control lowering of the leg

3 – abducts hip 90-100% of expected movement arc, able to control lowering of the leg, minimal compensations

iii) Hip abduction in Side-lying:

0 – legs do not move apart, or hip flexion only

1 – abducts hips 25% of the expected movement, may compensate with associated hip flexion

2 – abducts hips 26-90% of the expected movement, may compensate with moderate associated hip flexion (~30 degrees)

3 – abducts hips 90-100% of the expected movement, may have mild associated hip flexion <10 degrees

**Bridges**

i) Double leg:

0 – Hips do not clear the floor or just off the floor ~1cm

1 – Completes 25% of the expected movement, may or may not control lowering to floor

2 – Completes 26-90% of the expected movement, does not achieve full hip extension, somewhat controlled in lowering hips to floor
3 – Completes 90-100% of the expected movement, hips relatively extended at top, hips lowered to floor with control

ii) Single leg bridges:
0 – Hips do not clear the floor or just off the floor ~1cm
1 – Completes 25% of the expected movement, may or may not control lowering to floor, hips may be markedly oblique (45 degrees or more)
2 – Completes 26-90% of the expected movement, does not achieve full hip extension and hips may not be level (pelvis oblique up to 40 degrees), somewhat controlled in lowering hips to floor
3 – Completes 90-100% of the expected movement, hips relatively extended and level at top, hips lowered to floor with control

Hip Flexor strengthening:
To strengthen the muscles on the front of the hips
0 – Does not initiate movement or initiates movement but foot does not clear the floor
1 – Hip is flexed 30-45 degrees, trunk may flex forward as part of compensatory movement
2 – Hip is flexed 46-80 degrees, trunk may flex forward as part of compensatory movement
3 – Hip is flexed 80-90 degrees, trunk remains erect

Straight leg raises:
0 – foot of leg to be raised remains on table
1 – completes 25% of the expected movement (heel raised 3” or less), may compensate with knee flexion, may or may not control lowering leg to floor
2- Completes 26-90% of the expected movement (heel raised 4-11” from floor OR heel >18” from floor, may compensate with moderate knee flexion (~30 degrees), somewhat controlled lowering leg to bed
3 – Completes 90-100% of the expected movement with heel approximately 12 “ from the floor, knee straight or slightly flexed (<15 degrees), controls lowering of leg to floor

Sit to stands: (Single and double leg)
0 – Hips do not leave chair
1 – Partially stands up or falls back down before achieves standing positon, may or may not control sitting back down
2 – Stands up and somewhat controls sitting back down
3 – Stands up and lowers back down to chair with control
Squats:
0 – Does not initiate movement or completes <25% of the expected movement (hips/knees flex <20 degrees)
1 – Hips and knees flex 25-40 degrees, knees may contact each other
2 – hips/knees flexed 45-80 degrees, knees may contact each other
3 – Hips and knees flexed 80 degrees or more, knees do not contact each other

Hamstring Curls
0 – Foot is not lifted off floor
1 – Completes 25% of the expected movement (knee flexed up to 30 degrees), may have associated hip flexion, may or may not control lowering foot back to floor
2 – Completes 26-90% of the expected movement (knee flexed 31-80 degrees), may have associated hip flexion and hip may move into a bit of abduction, somewhat able to control lowering of foot to floor
3 – Completes 90-100% of the expected movement (knee flexed 80-90 degrees), may have associated hip flexion but thigh/knee/lower leg are aligned, controls lowering of foot to floor

Hip Extension in 4-point
0 – Knee or foot remains in contact with floor
1 – Completes 25% of the expected movement, may or may not control lowering of leg to floor
2 – Completes 26-90% of the expected movement, pelvis may or may not be level, knee may be moderately flexed, somewhat able to control lowering of leg to floor
3 – Completes 90-100% of the expected movement, pelvis level, knee is straight or mildly flexed ~10 degrees, lower foot to floor with control

Hip/Shoulder extension 4-point
0 – unable to lift arm and leg from floor
1 – Completes 25% of the expected movement, movement of leg and arm may be staggered
2 – Completes 26-90% of the expected movement, arm and leg movement simultaneous, may appear off balance
3 – Completes 90-100% of the expected movement with hip and shoulder at or nearly at 90 degrees, in control with simultaneous movement of arm and leg

Supermans
0 – arms or legs remain in contact with floor
1 – arms and/or legs (movement does not need to be simultaneous) momentarily raised from floor 25% of expected movement, may or may not lower with control
2 – arms and legs raised from floor in somewhat coordinated fashion 26-90% of expected movement, able to hold for minimum 3 seconds
3 – arms and legs raised from floor 90-100% of expected movement, able to hold for minimum of 5 seconds

**Reverse fly/scapular retraction**

Elbows can be flexed to 90 or extended or anywhere in between

0 – arms remain in contact with floor
1 – Completes 25% of the expected movement, with hand and elbow raised from floor 1” or less
2 – Completes 26-90% of the expected movement, (hand and elbow >1” from floor but >1” from being level with shoulder height)
3 – Completes 90-100% of the expected movement, elbows and hands level or within 1” of being level with shoulders

**Abdominal crunches**

0 – only head is raised from floor
1 – Completes 25% of the expected movement with top of shoulders raised from floor
2 – Completes 26-90% of expected movement – inferior angle of shoulder blade in contact with floor
3 – Completes 90-100% of expected movement with shoulder blades cleared from floor

**Lunges:**

0 – Does not step forward or steps forward but does initiate lunge (flexion), or falls with loss of balance before lunge movement is initiated
1 – Steps forward and lunges completing 25% of the expected movement (front hip/knee flexed <45 degrees)
2 – Steps forward and lunges completing 26-90% of the expected movement (front hip/knee flexed 45-90 degrees)
3 – Steps forward and lunges completing 90-100% of the expected movement (front hip/knee at 90 with opposite knee approaching floor)
Consort Form (For Parent Consenting on Child’s Behalf)
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

<Name of Person Obtaining Consent> explained this study to me. I read the attached Information Letter dated and understand what this study is about.

I understand that my child or I may drop out of the study at any time.

I agree to participate in this study and allow my child to participate.

Parent’s Name (please print)  Signature  Date

Participant’s (child’s) Name (please print)

I have explained this study to the above participant/parent and have answered all their questions.

Name of Person Obtaining Consent  Signature  Date

There are no perceived conflicts of interest on the part of the researchers of this study, their institutions or the research sponsors.

July 27, 2016
CONSENT FORM (for parent participating in interview)
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

<Name of Person Obtaining Consent> explained this study to me. I read the attached Information Letter dated and understand what this study is about.

I understand that I may drop out of the study at any time.

I agree to participate in this study.

Parent’s Name (please print)       Signature       Date

Name of Person Obtaining Consent       Signature       Date

There are no perceived conflicts of interest on the part of the researchers of this study, their institutions or the research sponsors.

July 27, 2016

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113
CONSENT FORM (for consenting child)
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

<Name of Person Obtaining Consent> explained this study to me. I read the attached Information Letter dated and understand what this study is about.

I understand that I may drop out of the study at any time.

I agree to participate in this study.

Participant’s (child’s) Name (please print)  Signature  Date

I have explained this study to the above participant and have answered all his/her questions.

Name of Person Obtaining Consent  Signature  Date

There are no perceived conflicts of interest on the part of the researchers of this study, their institutions or the research sponsors.

July 27, 2016  Page 7 of 8
CONSENT FORM (for consenting therapist)
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

<Name of Person Obtaining Consent> explained this study to me. I read the attached Information Letter dated and understand what this study is about.

I understand that I may drop out of the study at any time.

I agree to participate in this study.

Therapist’s Name (please print)  Signature  Date

I have explained this study to the above participant/parent and have answered all their questions.

Name of Person Obtaining Consent  Signature  Date

There are no perceived conflicts of interest on the part of the researchers of this study, their institutions or the research sponsors.

July 27, 2016  Page 5 of 6
OPTIONAL CONSENT FORM FOR PHOTOS AND VIDEO USAGE
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

I authorize the use of photos and videos from the present study where I/my child appear(s) for the following intiated purposes:

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<thead>
<tr>
<th>Purpose</th>
<th>I authorize the use of</th>
<th>I do not authorize either</th>
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<tr>
<td></td>
<td>Photos</td>
<td>Videos</td>
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<tr>
<td>Academic presentations at Holland Bloorview Kids Rehabilitation Hospital</td>
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<tr>
<td>Academic presentations outside of Holland Bloorview Kids Rehabilitation Hospital (in Canada and internationally)</td>
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<tr>
<td>Academic articles in journals and conference proceedings</td>
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<tr>
<td>Promotional multimedia on Holland Bloorview’s website</td>
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<td>Printed news and magazines articles</td>
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<td>Online news and magazines articles</td>
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Parent’s Name (please print)                  Signature   Date

Participant’s (child’s) Name (please print)   Signature   Date

Name of Person Obtaining Consent               Signature   Date

July 27, 2016

Page 8 of 8
Appendix I

Queen’s HSREB Approval Letters

QUEEN’S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD (HSREB)

HSREB Initial Ethics Clearance

September 08, 2015

Dr. Nicholas Graham
School of Computing
Goodwin Hall

ROMEO/TRAQ: #6016281
Department Code: SCOMP-017-15
Study Title: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy
Co-Investigators: Dr. D. Fehlings, Dr. H. Hernandez, Dr. E. Biddiss, Ms. L. Fay
Review Type: Delegated
Date Ethics Clearance Issued: September 08, 2015
Ethics Clearance Expiry Date: September 08, 2016

Dear Dr. Graham,

The Queen’s University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) has reviewed the application and granted ethics clearance for the documents listed below. Ethics clearance is granted until the expiration date noted above.

- Protocol:
- S-PACES Questionnaire
- IMI Questionnaire
- PENS Questionnaire
- Custom Feedback Questionnaire
- Recruitment Telephone Script
- Recruitment Flyer
- Recruitment Clinician Script
- Recruitment Letter
- Recruitment – HBKRH Webpage
- Assent Form – June 08, 2015
- Consent Form – June 8th, 2015

Documents Acknowledged:

- TAHSN REB Application
- Approval – Holland Bloorview Kids Rehabilitation Hospital – July 23, 2015
Amendments: No deviations from, or changes to the protocol should be initiated without prior written clearance of an appropriate amendment from the HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

Renewals: Prior to the expiration of your ethics clearance you will be reminded to submit your renewal report through ROMEO. Any lapses in ethical clearance will be documented on the renewal form.

Completion/Termination: The HSREB must be notified of the completion or termination of this study through the completion of a renewal report in ROMEO.

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information.

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete.

Yours sincerely,

[Signature]

Chair, Health Sciences Research Ethics Board

The HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations, Canadian General Standards Board, and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is qualified through the CTO REB Qualification Program and is registered with the U.S. Department of Health and Human Services (DHHS) Office for Human Research Protection (OHRP). Federalwide Assurance Number: FWA#:00004184, IRB#:00001173

HSREB members involved in the research project do not participate in the review, discussion or decision.
QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD (HSREB)

HSREB Amendment Acknowledgment/Ethics Clearance

October 17, 2017

Dr. Nicholas Graham
School of Computing
Goodwin Hall
Queen's University

ROMEO/TRAQ: #6016281
Department Code: SCOMP-017-15
Study Title: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy
Review Type: Delegated
Date Ethics Clearance Issued: October 17, 2017

Dear Dr. Graham,

The Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) has reviewed the amendment application and granted ethics approval/acknowledgement for the following:

- Addition of MSc student – Jesse Liam Collins
- CORE Certificate – J.L. Collins
- Request to evaluate a virtual reality therapy game, Bootle Rumble, at Holland Bloorview Kids Rehabilitation Hospital (HBKRM) in Toronto
- Holland Bloorview Ethics Submission
- Holland Bloorview HSREB Approval Letter – May 30, 2017

Yours sincerely,

Chair, Health Sciences Research Ethics Board

The HSREB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations, Canadian General Standards Board, and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is qualified through the CTO REB Qualification Program and is registered with the U.S. Department of Health and Human Services (DHHS) Office for Human Research Protection (OHRP). Federalwide Assurance Number: FWA#:00004184, IRB#:00001173

HSREB members involved in the research project do not participate in the review, discussion or decision.
Appendix J

Holland Bloorview Kids Rehabilitation Hospital REB Approval Letter

Holland Bloorview Research Ethics Board
Amendment Approval Notification

Holland Bloorview Research Ethics Board operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations, Part 4 of the Natural Health Products Regulations, Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA, 2004) and its applicable regulations. Holland Bloorview Research Ethics Board is qualified through the CTO REB Qualification Program and is registered with the U.S. Department of Health and Human Services (DHHS) Office for Human Research Protection (OHRP).

Study Title: Project VRTs: Exploring technologies for virtual reality therapy of young people with cerebral palsy
File Number: 15-578
Principal Investigator: Elaine Biddiss
Co-Investigators: Ajmal Khan, Darcy Fehlings, Linda Fay, Nicholas Graham, Lukasz Wawrzynski, Denis Nik ten, Daniel Scott, Liam Collins, Char Richards, Nicholas Vignais, Vincent Vigneron
Amendment Approval Date: January 3, 2018
Study Expiry Date: July 20, 2018
Review Type: Delegated

January 3, 2018

Dear Dr. Biddiss,

The Holland Bloorview Research Ethics Board (REB) has reviewed the amendment to the above named study. The board is granting ethics approval for the amendment dated November 11, 2017. The approval of this amendment includes the following documents:

- Informed Consent Form - Participants (version 9 dated 11/11/2017)

REB members involved in the research project do not participate in the review, discussion or decisions.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Alison Williams, PhD
Chair, Research Ethics Board
P: 416 425 6220 x3724
awilliams@hollandbloorview.ca

A world of possibility
Appendix K
TCPS 2: Core Certification

Certificate of Completion

This document certifies that

Liam Collins

has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)

Date of Issue: 19 June, 2015