Virtual Pet Companion

A digital console to enhance the Experience of Children with Cerebral Palsy

By

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ABSTRACT

This research investigates the use of game style consoles as service technology for children with Cerebral Palsy, in order to help them develop their fine motor skills and thereby become more independent in interactions with family and caregivers. The game involves a virtual pet companion for a six-year-old child with Cerebral Palsy currently living in Toronto. It was designed specifically to cater to his interests and needs; however, this research more broadly seeks to explore the potentiality of video games for rehabilitation for children with Cerebral Palsy, taking into account the propensity and interest children often have for new technologies. Drawing from research on Cerebral Palsy, the psychology of play, existing service technologies for children with disabilities, pet therapy and gamification, my project provides insight into how new interactive technologies can afford children with Cerebral Palsy the opportunity to interact more easily with the physical world.

Keywords:

User experience design, designing for disability, inclusive design, cerebral palsy, Gamification, Augmented Reality, Mobile app, Children , Assistive technology.

Dedication

This work is dedicated to my family

my parents, my siblings

and my cousin Faisal

I couldn’t have done this without you.

Thank you for all your love and support throughout my life.

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3 Introduction

3.1 Motivation

All forms of disability have the potential to contribute to a sense of social and cultural alienation for children. Alongside the gifts that children with special needs bring, disabilities can also bring added pressure and responsibilities for immediate families in support roles. This can result in frustration for individuals who want to achieve self-determination. I have always been interested in the potential to harness both high and low technology tools in order to better serve people with disabilities (PWD), enabling PWD of all ages to be more independent in communicating and interacting with other people and in their daily lives.

I grew up with a relative who is physically challenged; this experience instilled in me a sense of empathy for people who face disabilities and a determination to help improve their conditions. This personal experience has also given me first-hand knowledge of the challenges disabled children and their families face, particularly in the Saudi Arabian context. Saudi Arabian society's view of PWD is based on the notion that disability equates to helplessness, continuous dependence, being homebound, low quality of life and lack of productivity. As an artist and a designer, I am interested in developing a platform that can provide both motivation and inspiration to PWD; I believe that new technologies have a lot of potential in this regard. The market for technologies designed for PWD is now a multibillion-dollar sector. In 2016, the global market for assistive (King, 2011). A number of inventions have been made available to make everyday living easier. An example of this is The DynaVox EyeMax System, which is designed to give individuals with paralysis, Cerebral Palsy, and those suffering the effects of strokes the ability to participate in spoken communication using only their eyes. Another device, the Kapten PLUS Personal Navigation Device, is a small GPS locator designed to help people who are visually impaired navigate cities. Much has been achieved in the field of technology and design for people with disabilities, yet they still face significant barriers that technology has the potential to ameliorate. Assistive technologies are evidently an emerging field to which artists and designers have a lot to contribute.

My interest in new and interactive assistive technologies for children with disabilities led me to read Margaret A. Boden's book, *The Creative Mind*, which explores how great inventors in history often developed their ideas while engaging in activities unrelated to their eventual inventions (Boden, 1992, p. 15). These ideas are described as "mysterious mental processes," and are a clear indication that one does not have to be highly knowledgeable or skilled in a specific subject to have a creative mind. According to this book, Archimedes solved how to measure the volume of irregular shapes while he was lounging in a bathtub. Friedrich founded the ideas of aromatic chemistry while he was sleeping. Similarly, Henry Pointcare discovered fundamental mathematical properties while boarding a bus (Boden, 1992, p. 25). However, aside from 'creative flashes' that come unexpectedly, the ability to invent also involves other unconscious aspects, some of which remain mysterious and unknown (Boden, 1992. P. 28). In their book review, Patterson and Thomas (2007) consider the ways that computers can augment and enhance the human gift of creativity. They ask whether the "computational concept can assist in understanding human creativity and whether the computer, by itself, can be "creative;" finally, they ask whether a "computer can recognize creativity" (Patterson & Thomas, 2007, p. 1). They define creativity as either "a re-combination of familiar items to form new one" or "an exploration of an established concept to discover new and perhaps unexpected possibilities" (Patterson & Thomas, 2007, p. 2). I was inspired by the second definition to explore the potentialities of interactive new technology and assistive devices for assisting people with disabilities.

This thesis seeks to develop a digital video game console that will help children with Cerebral Palsy in wheelchairs to influence the physical world around them. This research explores and analyzes elements that come into play when creating a playful experience for a child with Spastic Quadriplegia. More broadly, this research attempts to evaluate and improve upon tools designed to serve people with disabilities, and help children with disabilities become more independent in their interactions with family and loved ones. This research involves the combined use of two different research approaches: Research as Prototype and User-Centered Design. I selected these methods in order to create a product specifically suited to the needs of my subject.

3.2 Thesis Structure

The aim of this thesis project is to integrate the different research methodologies to find solutions to the day-to-day problems encountered by children with Cerebral Palsy; to this end, I designed The Companion, an app that has borrowed ideas from different research fields, including disabilities studies, assistive technologies, pet therapy, and the psychology of play. In the next chapter, I will provide an overview of Cerebral Palsy (CP), discuss available assistive technologies and illustrate effects of Gamification on wheel-chair bound children; then, I will examine the benefits of pet therapy and Augmented Reality on the emotional and social development of children. I will argue that the Companion App will provide children in wheelchairs with both emotionally and socially positive experiences.

For the preliminary research for this thesis, I conducted several interviews with a young relative in Saudi Arabia who suffers from Cerebral Palsy. He is not the subject of my study; however, the interviews with my relative provided me an initial research direction and inspiration for my project. I remain in dialogue with him in regards to the progress and value of my work; these dialogues are conducted by proxy with his mother due to time difference issues.

My primary research for this project involved a series of experimental prototypes using digital technologies that were used and evaluated by John, a six-year-old boy with Cerebral Palsy living with his parents in Toronto. During the research and testing processes, I engaged directly with John and his parents, with the aim of developing and evaluating technology that would specifically meet the needs of John and his family.

4 Literature Review

4.1 Cerebral Palsy

Cerebral Palsy (CP) is a range of “non-progressive syndrome[s] of posture and motor impairment” that results from brain damage to a child at birth or during infancy—an injury to the “central nervous system” from which a child does not “recover, nor do they tend to worsen” (Rosenbaum, Paneth, & Goldstein, 2007, p. 9) based on medical evaluation and monitoring (Sandllund, 2011, p. 23). There are three main types of Cerebral Palsy: hemiplegia, diplegia and quadriplegia (Gormley, Krach, & Piccini, 2001, p. 127). John has been diagnosed with spastic quadriplegia Cerebral Palsy that affects the movement of his whole body. As a consequence, he has little control over his four limbs and his mouth muscles. Additionally, it takes some effort for him to control his head. His cognitive abilities are also slightly affected. According to Gormley, Krach, and Piccini (2001), “also described as ‘whole body involvement’, spasticity can interfere with motor function, contributes to the development of deformities and adversely impacts on care, positioning, and comfort” (p. 127). Speech, vision, hearing, cognitive abilities and learning can also be impaired (Gormley, Krach, & Piccini, 2001, p. 127).

4.2 Cerebral Palsy Classification Systems

Motor impairments affected by ‘Irregular motor functioning’ are a fundamental condition of Cerebral Palsy. The intensity of motor abilities differs between minor limitations of hand/leg movements and severe cases (Sandlund, 2011, p. 24). As CP has widely varying levels of severity depending on the case, classification systems have proven instrumental for clinicians in delineating the severity of individual cases and prescribing therapy, treatments and assistive technology (Eliasson et al., 2007, p.594). Two classification systems – the Gross Motor Function Classification System and the Manual Ability Classification System – are used by clinicians to define the patient's ability to function. This first classification – the Gross Motor Function Classification System (GMFCS) – is a five-level system that gives details needed for appropriate treatment or care on the basis of self-initiated movement abilities (Sandlund, 2011, p. 24) with stress on the role in 'sitting and walking' (Eliasson et al., 2007, p. 594). This method of classification has been adopted worldwide. John's functions according to this classification system are as follows:

Table 1: *John's Gross Motor Function Classification System (GMFCS) levels.* Retrieved from Sandlund, 2011, p. 24.

GMFCS IV (Primarily)	Children use methods of mobility that require physical assistance or powered mobility in most settings. They may walk for short distances at home with physical assistance or use powered mobility or a body support walker when positioned. At School, outdoors and in the community, children are transported in a manual wheelchair or use powered mobility.

GMFCS V (Secondarily)	Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control leg and arm movements.

Motor Function Classification System is also used to classify the level of functional severity and movement of upper extremity and fine motor function. According to Eliasson et al.'s (2007) *The Manual Ability Classification System (MACS) for children with cerebral palsy: Scale development and evidence of validity and reliability*, the Manual Ability Classification System (MACS) "describes how children with cerebral palsy use their hands to handle objects in daily activities. The levels are based on the children's self-initiated ability to handle objects and their need for assistance or adaptation to perform manual activities in everyday life" (p. 594). Details of the MACS levels that describe John's case are showed in Table 2 below.

Table 2: *John's Manual Ability Classification System (MACS) levels.*
Retrieved from http://www.macs.nu/

MACS V (Primarily)	Does not handle objects and has severely limited ability to perform even simple actions. Requires total assistance
MACS IV Secondarily)	Handles a limited selection of easily manage objects in adapted situations, requires continuous support.

4.3 Assistive Technology for Children with Cerebral Palsy

For cognitive development of physically challenged children, movement and development researchers have identified the need for motor experience in such children who find it difficult or impossible to explore their surroundings unaided or unaccompanied (Alvarez et. al., 2013, p. 905).

Assistive technologies assist children with physical and cognitive disabilities in performing daily activities and gaining motor experience. According to the organization United Cerebral Palsy (2015), "assistive technology is every item, piece of equipment, software or product system that is used to increase, preserve or develop the functional capabilities of individuals with disabilities". The organization emphasizes how "vital the roles played by these products are in the lives of disabled people" (United Cerebral Palsy, 2015). Coombs (1990) posits that, "the use of assistive technology by the disabled goes back into prehistoric times. The primitive humans must have fashioned clubs and axes to facilitate hunting and gathering; others must have designed crutches and canes to compensate for physical handicaps" (p. 1).

Children with CP require practice and exercise using objects; without this motor experience, a child's ability to hold and use objects may become limited. This may "affect the quality of their play and learning skills" (Alvarez et. al., 2013, p. 905). In such situations, assistive technologies can facilitate manipulation for children to improve their growth, understanding and learning (Alvarez, Rios, Adams, Encarnação, & Cook, 2013, p. 905). Campos, in the paper *From Infancy to Early Childhood: The Role of Augmentative Manipulation Robotic Tools in Cognitive and Social Development for Children with Motor Disabilities*, states that motor experience helps in cognitive and perceptual delays (Alvarez, Rios, Adams, Encarnação, & Cook, 2013, p. 905). It is clear that assistive technologies can provide opportunities for environmental exploration for young children with disabilities. As such, there are a number of new technologies, including video games, specifically designed for children with motor impairments. Below, I highlight some of the devices that revolutionize the use of gaming technology for server cases of disabilities.

Assistive technology tools have different variations according to the physical capabilities and clinical diagnoses of a child. For example, Timocco software, a gaming system designed to accelerate the development of motor and cognitive skills, works with a web cam and a browser to track body movements. This is designed for children diagnosed with autism, sensory processing disorder, CP, and nonspecific motor and cognitive disabilities. It is adjustable to match every individual child's need, ability and challenge. This product has been praised by occupational therapists for its effectiveness in coordinating the child's hands and developing the child's upper body strength as well as their body awareness (Sarit, 2012, p. 359).

One advanced assertive technology tool that designed for severe cases of CP and for children with limited speaking abilities is the eye-gaze device. This device enables a person to use eye movements to operate a computer or a tablet. The virtual reality system developed by FOVE is a good example. Virtual Reality is defined as "the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence" (Bryson, 1996, p. 1). This company produces the world's first eye tracking virtual reality headset that enables patients who have lost the use of their hands to use eye tracking. The headset reacts to users' eye movements and emotions, offering precise control at the speed of thought.

These existing technologies compensate for the children's limitations, enabling them to use their strongest abilities to control or interact with objects and people or to strengthen and encourage the use of their weaker abilities in entertaining ways. These technologies informed my game, in which I used a simple input device that controls a complex and entertaining game using something that John is already familiar with and exposed to.

4.4 Children's Play

Naturally, children find play activities captivating and enjoyable, and have an internal desire and interest to participate in them; this is, in fact, a vital part of their physical, mental and psychological development (Verenikina, Harris, & Lysaght, 2003, pp. 1-2). In the article *Child's Play: Computer Games, Theory of Play and Children's Development,* the authors describe the history of theories on play and development. They quote theorists including Vygotsky and Bodra (1977) and Leony (1996), who describe the significance of play in child development as “the most leading activity in early childhood years” (Verenikina, Harris, & Lysaght, 2003). Some other theorists such as Freud (1959,1968) and Erikson (1963) similarly support this claim, and are quoted in the paper adding that such play activities must be repetitive so as to help children reduce stress and help improve their confidence and emotions (Verenikina, Harris, & Lysaght, 2003, pp. 2-3). In the paper, Verenikina, Harris, and Lysaght (2003) mention how Vygotsky (1978) saw play as an extremely important aspect to development. He states, “play contains in a concentrated form, as in the focus of a magnifying glass, all developmental tendencies” (p. 3). Since children have little autonomy over their lives and constantly rely on other people, I attempted to create a game that allows children to use familiar devices to play in an immersive and interactive way to extend the time they use their hands. With the goal of engaging users with a virtual animal companion in mind, I investigated the association between pet therapy games and rehabilitation.

4.5 Virtual Pet Therapy

According to Anger and Akins, pet therapy, also called “animal-assisted therapy” (396), can help patients with their physical activities, psychological welfare, cognitive performance and social development. They state that the companion pet should be living with the patient in order to offer them ease and assistance at all times (Anger & Akins, 2014, p. 397).

Virtual pets may be able to provide some of the same comforts. Kritt (2000) reflects on the impact of virtual pets, which offer the compact size, extreme maneuverability, and addictive appeal of other electronic games. According to Chen, Liao, Chien, and Chan (2011), using virtual characters for education purposes "foster[s] both user interface and behavior cultivation" (pp. 166-67). The user interface of these virtual pets has the benefit of being more compelling to the students than using only images and texts. The friendly nature of the characters and their interesting appearance helps engage students, thus 'increasing their motivation'. There have been a number of educational virtual companions dedicated to guiding students' "learning behaviours, such as exploration, reflection and articulation, communication, and negotiation" (Chen, Liao, Chien, & Chan, 2011, p. 167). Animating the character to re-enact human-like movements and expressions, such as smiling, posture, movement and tone of voice, expands the connection between user and virtual pet and further adds to the molding of these critical practices. The authors posit that through interacting with animal companions, "users become more aware of their learning status" (Chen, Liao, Chien, & Chan, 2011, p. 167).

A great advantage of associating rehabilitation with fun game-like components is that it makes the procedure will be more pleasant, prompting lengthier sessions and less defiance from young users. Chen, Liao, Chien, and Chan agree that "the incorporation of adequate principles of gaming design can positively facilitate learning, including within formal-structured schooling" (p.

169). Tamagotchi, a pocket-sized virtual pet digital game created in 1996, is a good example of successful pet companion gaming. Digital games have the potential to shape young students' mannerisms (Chen, Liao, Chien, & Chan, 2011, p. 177). Similarly, digital games are good means to influence young students' behaviors. Chen, Liao, Chien, & Chan (2011) note that the two techniques most commonly utilized in the creating of the framework to reflect user learning endeavors are "mirror of learning profiles and work-centered learning models" (p. 168). In another paper, the same authors posit that digital games have been noted to shape students attitudes and behaviour (p. 251). Goal setting, a primary component of many games, is a vital basis of inspiration and serves as a standard against which to 'evaluate performance' as per the fundamentals of social cognitive theory. As the authors note, the experience of finishing an objective is a primary driver of self-adequacy; users feel a gratifying sensation of achievement at the point when the objective is achieved, and then they proceed to set higher objectives (Ahn et al., 2015, p. 810).

Stendal, Balandin, and Molka-Danielsen (2011) note that virtual worlds have been utilized to help individuals with developmental disabilities develop their social skills. Recently, some assistive games have created scenarios meant to echo particular social events, which users play in order to improve learning and comprehension "to be used in real worlds". The authors posit that "a simple virtual world can be created for people with intellectual disability to perform a particular task until it becomes familiar." They state that virtual worlds permit the introduction of new functions that can be altered and upgraded from time to time to enrich the experience, enabling this technology to support many forms of “new learning” (Stendal, Balandin, & Molka-Danielsen, 2011, p. 81). Virtual companions and interactions in general can add to children's developing opinions and “experiences of emotion and self” (Kritt, 2000, p. 84). Lakoff and Johnson (1981) also confirm that “unconscious root metaphors for understanding ourselves and our world, as well as conscious idioms and ideologies, give form to subjectivity and have the capacity to transform human thought and action to such an extent that it comes to be regarded as what is called ‘natural symbols’”(Kritt, 84).

4.6 Augmented Reality

> Barker defines Augmented Reality in *Build mobile apps: The complete guide* as follows:
>
> Augmented Reality (AR) is a way of blending together visual images from the physical and real world. This blending happens in real time in 3D space interactively as a user moves around. With mobile devices, AR makes use of the device screen and camera, turning the screen into an optical see-through (OST) display. The screen shows the camera view but with computer graphics superimposed and aligned according to what the camera sees, or the phone’s location sensors, or geolocation data, or any combination. (259)

This technology is growing tremendously in the fields of entertainment and education. Thus, augmented reality can be seen as a conduit for bringing together education in virtual environments and in the real world. Several theorists, including Bower, Mc Credie, Johnson and Zuma, have noted that augmented reality is, “becoming more ubiquitous in nature” (Bower et. al., 2014, p. 1). The authors of the paper *Augmented Reality in education – cases, places and potentials*, discuss several technologies that can be utilized to improve user experience. Augmented Reality becomes especially useful as an educational tool when used in conjunction with "GPS Technology that allows the system to take into account the user's real-world location, ensuring that contextually relevant virtual data is provided to the user at geographically significant locations". Similarly, "image recognition software enables real-world images and objects to act as triggers" for multimedia and model overlays, and also to anchor virtual data in the environment" (Bower et. al., 2014, p. 2). One more fascinating use of augmented reality is gaming. Augmented reality makes it possible to create new types of games that involve both physical and virtual worlds.

Augmented Reality has recently shifted towards a mass-market, accessible context. This project targets low-cost mobile devices such as laptops, tablets and mobile phones rather than expensive and specialized devices. An important goal of this project is to utilize augmented reality to come up with an intuitive and immersive game that also provides an enriching experience for children with Cerebral Palsy.

5 Methodology

5.1 Overview

This thesis involves the combined use of two different research approaches: Research as Prototype, and User-Centered Design. Given that this project is user-centric in nature, a user-centered design process is absolutely necessary. Creating a game for my subject required understanding the context of use and observing the subject, his family, his environment and the way he engages and communicates. It was also necessary to use research as prototype to test out the prototype with the subject and refine it according to his needs. Throughout the research process, I researched and tested technologies that might better serve this project. Analyzing techniques while testing the prototype led to the final iteration of this project. Using both methods resulted in a holistic research process that heavily incorporated user input and was ultimately focused on delivering a product tailored to the needs of my user.

5.2 Field Research

The preliminary stage of research began with a series of interviews with an 11-year old from Saudi Arabia who has Cerebral Palsy. The interviews were conducted by proxy with the subject and his primary caregiver due to time difference and distance issues. This provided an initial direction for the project in terms of further steps and necessary research. The primary stage of the project involved a series of semi-structured interviews with key questions meant to determine potential areas to be investigated and to discuss certain issues that might arise.

Interview questions directed towards the boy's parents were open ended. For example, they were asked to describe a typical day for their child from the moment he wakes up to the time he goes back to sleep, including his biggest challenges and his communication with others. The subject was also asked several open-ended questions; he was asked what his favourite games are and what activities are the most difficult for him, among others. Some of the keywords generated from this stage included: wheelchair, social interaction, gamification, independence, and assistive technology. Following these interviews, I conducted a similar interview with my subject, John, and his family, who live in Canada.

Cultural differences between Canada and Saudi Arabia, especially in regards to social and cultural infrastructures surrounding mental health, became clear when I examined my interviews with the initial subject in Saudi Arabia and later with the user in Toronto. Saudi Arabian society carries stigmas against people with mental and physical disabilities and differ-abilities; families have to face negative social attitudes and the absence of accessibility. The mother of the Saudi Arabian subject identified several problems her family faces that simply do not exist in Toronto. For example, she stated that she worries about the lack of assistive technology, transportation and school involvement for her son. On the other hand, John's parents' concerns mostly considered the future of their son and how to prepare him to be independent; they do not have to worry about transportation and involvement in school to nearly the same extent. Both children shared the same fascination with technology and had similar taste in games. Evidently, when designing or conducting research about disability, factors like cultural and social attitudes should be considered and evaluated. After the initial interviews with the subject from Saudi Arabia, I gained a deeper understanding of Cerebral Palsy and its repercussions. From the conversations with his parents, it became apparent that the needs and challenges of each individual with Cerebral Palsy differ, although there are some common aspects. Due to these individual differences, I examined how technology could assist with the user's communication.

Following the interviews with the initial subject in Saudi Arabia, I developed ideas based on my findings in order to map out a direction for my thesis. I knew at this stage that I wanted to create something to help with the physical rehabilitation process of my user, John. His interests in digital games and the pain associated with physical therapy stood out from our talks; the latter was one of the main things that bothered him and affected his family, who struggled especially in the beginning stages of therapy when he was younger. The physical pain experienced daily by John as a result of therapy took a toll on the whole family. I was determined to find a solution that would help ease this process. The most difficult aspect of this was conceiving a direction or solution that could be implemented in other cases. I began researching current methods of assisting children and adults with this problem. During the research process, I found out about the tremendous advantages of pet therapy. I also examined the possibilities of creating a virtual animal and I found some research (documented in the literature review section) that discussed the positive effects of virtual animals on children with disabilities. Given this research, I decided to explore how to implement this method in John's situation and how it might be applied in different cases.

5.3 A Day in the Life

Milton and Rodgers (2011) state that the "day in the life" method is intended "for revealing unanticipated issues inherent in the routines and circumstances [that] people may experience on a daily basis" (p. 27). This technique is different from other observational methods such as shadowing, in which the process of gathering information is maintained over an extended period. A common day in the life is conducted over one full day over a period of twenty-four hours or perhaps over the typical eight hours of a workday (Milton & Rodgers, 2011, p. 27). In order to correctly use this technique, the researcher must observe and record the user's activities and environment while ensuring that they are noticed as little as possible (Milton & Rodgers, 2011, p. 27). I employed this method in the early stages of this research. I observed John with little intrusion and carefully took notes based upon the ways he interacted with the world around him and the type of play activities he was involved in.

Milton and Rodgers also outline a set of guidelines on how to achieve efficient results while using the "day in the life" method. They note the importance of preparation and investing time to learn more about the users and their environment, compiling significant notes either based on major events or on different time slots while using films and audio, and on examining the data by sorting the information and isolating themes into clear groups (Milton & Rodgers, 2011, p. 45).

I gathered data on my user over three separate sessions at his house and his school to compile a realistic image of his typical day and to create a balanced frame of reference. The first and the second sessions took place at John's house, during which I observed him interact with his parents and sibling with very little involvement from my side. The third session took place at his school, where I observed how the teachers and students interacted with John and the assistive technologies he used. I took comprehensive notes and made audio/video recordings during these sessions.

John has very particular tastes and interests; during my observation sessions it was immediately clear that he prefers loud noises, sudden actions, music, brightly coloured, strong lines, and abstract illustrations. I sat in the corner while he watched one of his favorite movies, *Mary Poppins*. Most of the scenes that got him excited and giggly were when something went wrong or unexpected, as well as musical scenes. His parents agreed with this observation, telling me that "music is a big part of his life" (personal communication, February 11, 2016). Based on this, I decided to apply music and sound to my prototype; this extended his attention span and immersion.

In terms of communication, John's parents know how important it is to establish a method for him to express his opinions, needs and thoughts to the rest of the world, and they are always looking for ideas and tools to help him with this. His current means of communication includes his voice and limited hand gestures.

When communicating with regard to intangible objects either on the screen or on a paper, John was presented with four groups of objects. The communicator started with the top-left object and moved it left to right, pointing at each option in turn and reading it aloud, asking John if the object was in that group. If he answered with a yes, they read aloud and pointed to each of the four items again, one at a time, pausing three seconds between each, until he used his voice to make a selection. If he did not respond but was clearly looking at a specific item, he was provided with feedback by the communicator to let him know that they understood; the communicator would say something like, "I think you might be looking at... Can you tell me yes with your voice?" If he failed to respond and did not look at anything, the communicator made it clear to him that they were not sure about his preference.

The second method of communication involved use of his hands, which is useful with real objects. In this method, John was presented with two objects, such as storybooks or movies, in front of him. The items were introduced individually by labeling and showing them to him, but they had to be within his arms' reach. If he reached towards an item with one of his hands, he was provided with feedback that he had been understood and was given the object. If he failed to respond but looked at a specific item, similar to the previous example, he was informed that he has been understood but he had to stretch his hand to take it. In order for these methods to continue being effective, it was important to be consistent and to keep letting John know how he should respond.

After observing John and the tools he used to communicate, it became clear to me that the ideal method was to use the same tools that he is already familiar with. This concept helped guide and shape the game play, design and input of my app.

During one occupational therapy session at school, the specialist was conducting an individual session with John in which he played an educational game. The game involved pushing a button upon hearing a sentence, at which point was presented with four choices. When the option he wanted was highlighted, John was required to push the button again. In the fifteen-minute session, he only pressed the button three times. It was apparent that he wasn't interested in the game, so the session was terminated. This taught me two things. Firstly, after observing John and learning his interests and preferences, it became apparent to me that the design app interface is important. The bland colours and small images might have affected John's motivation, making the game uninteresting to him. Secondly, patience is vital, as the process of communication and getting a response takes a long time sometimes. I had to give John time and be patient, present and active whenever he needed to be encouraged. This helped tremendously in the testing phase of the project. Another factor I noted was choosing the right time to test John. Prior to the first observational session, I waited for about an hour because John wanted to take a nap and rest. Testing John at the wrong time could lead to negative test results regardless of the quality of my game.

During these observation sessions at his school, I noticed that John would lose interest during oral story time sessions in class; his eyes would wander and he would eventually lay his head on the table. However, if the teacher brought his favourite book close to him, or left it on his table, he would stay interested and active for much longer; as such, I hypothesized that a game for a mobile device such as a tablet, which can be placed on his table close to him, would help him stay focused and thus extend the duration of play sessions.

5.4 User-Centered Design: Participatory Design

Palisano et al. (2012) carried out a study on ways to encourage children with disabilities to take part in research programs. The main aim of the study was to find out how to maximize home and community participation of children with physical disabilities. Participation can be defined as "involvement in real life situations, reflecting the interaction of the person, activity and environment" (Palisano et al., 2012, p. 1041) "throughout the entire research and development process" (Gkatzidou et al., 2015, p. 132). In my case, because of John's limited cognitive ability and speech impairment, it was absolutely necessary to involve people who know and care about him in the design process so as to create a design solution that would cater to his needs.

Observations by Palisano et al.(2012, p.1042) note that several factors contribute to high participation, including the personality of the participating child, the support of his/her family, the nature of the surrounding environment, and the extent of his/her physical and social involvement. While observing John and his parents, I noticed that John's personality somewhat changed between a quiet person at school and a more engaged and active person at home. Additionally, I paid close attention to his gestures and facial expressions during observation sessions, which helped me understand him and interpret his actions in the testing phase. For instance, I watched his facial expressions to distinguish between him becoming frustrated while playing the game and him taking his time to press the buttons and the try the game again. This method was helpful in providing context for the subtle nuances of John's preferences and demands. The constant input of John's parents in the design process and their profound feedback provided valuable insights that defined the priorities of this thesis.

Rubin, Chisnell, and Spool (2008, p. 17) argue that researchers who use the technique of user-centered design run the risk of becoming too close with the user, who might withhold crucial information so as to avoid disappointing the researcher. I kept this mind when communicating with John and his parents.

5.5 Prototype as Research

Lim, Stolterman and Tenenberg (2008, p. 9) define prototypes "as a tangible attempt to view a design's future impact so that we can predict and evaluate certain effects before we unleash it on the world". They state that prototypes and the development of ideas are greatly interwoven during the "design process" (Lim, Stolterman & Tenenberg, 2008, p. 9). They also explain that the importance of prototype lays in the idea of intensive reflections that help the researcher structure, enhance and uncover potential in the design (Lim, Stolterman & Tenenberg, 2008, p 2). Prototypes can be used in diverse situations and for different purposes. The main objective of developing prototypes in the early stages of a design process is to detect problems or find alternative directions for new results. This means that even if the prototype is not developed to a final product, some elements are filtered out (Lim, Stolterman & Tenenberg, 2008, pp. 8-9). This filtering process was crucial during the experimental phase, when I tested different input devices to find the most suitable one for my purposes. It has also been useful in comparing and recognizing the improvement with each generation of prototype.

The authors also argue that sketching is vital to the research process. This can be done using whatever tool is important to the object behind the design: it can be done in the formation of simple text or images, and later on, it can become more complex as the design is developed and polished (Lim, Stolterman & Tenenberg, 2008, p. 11). In the beginning stages, over the course of four weeks, I developed ideas using sketches, including illustrations and texts. By analyzing each idea and sketch, I identified possible complications and future limitations. I started sketching different keywords and features that I wanted to implement in the project, followed by more detailed illustrations. In doing so, I located points of strength and weaknesses of the refined models in the development and design process.

5.6 Summary

This project is tailored to the needs of one specific user; as such, a combination of several different research methods and techniques was necessary to create a successful product. I received valuable input and feedback from the parents at every stage of the design process; this was essential to the success of the project. These interactions and my observation sessions with the subject carried the potential to reveal immanent potentialities for my research; this allowed me to refine the parameters of my project while also necessitating constant revisions when unexpected insights made certain avenues or ideas impossible. This immanent process ultimately strengthened the research and was necessary in the development of an effective and entertaining game.

6 Developments and Design Process

6.1 Overview

For my research, I wanted to evaluate whether access to interactive games based on pet therapy would increase John's use of his hands, in order to give him a tool to further engage with the physical world around him. I examined previously published research and collected evidence for the application of virtual pet therapy in the rehabilitation of children with disabilities. The research started with a discovery stage in which I conducted a series of interviews with a male Saudi Arabian child, who suffers from CP, and his parents. Following this, I utilized several research methods with the main user, John, and his caregiver, starting from observation sessions and eventually testing prototypes in order to observe John's levels of motivation to exercise using the games.

My project conceptually began as an interactive pocket size cube, which could be easily held and carried around by a child's hands. This cube would integrate physical and digital elements by using Augmented Reality: digital content would be overlaid on top of a view of the physical world through the camera of a phone or tablet interacting with the cube. The prototyping process was divided into two parts: a low fidelity prototyping stage and a high fidelity stage. The low fidelity stage was designed to evaluate the general forms of interactivity allowed by the cube interface and to identify any technical problems. After eliminating and identifying the key elements of the game and modifying the design, I proceeded to the second series of tests, which involved user testing a constructed high fidelity prototype with John. Ultimately, the main goal of this design process was to create an immersive and interactive game revolving around a virtual pet companion on an easy and intuitive platform.

6.2 Low fidelity prototype

In this section, I will describe the first stage of the design process, in which I constructed and tested a low fidelity prototype of my project. I will illustrate the process by which I chose my design and control scheme; I will also discuss the physical limitations and considerations involved in the initial design.

6.2.1 Stage 1: Technology

Augmented Reality

Since I was unfamiliar with Augmented Reality (AR) at the commencement of this thesis, I conducted extensive research and examined current and past projects in order to understand different methods of implementing AR. First, I considered the available applications for AR. There are several options on the market, but they are very limited when it comes to creating games. One of the more promising options was the DAQRI 4D Studio, which helps users create augmented reality projects with no prior coding knowledge. However, it was suspended for new users since they are planning to shift their focus to industrial applications. Eventually I settled on using the Unity game engine and Vuforia, an Augmented Reality Software Development Kit. Vuforia was the most suitable software for this project because it is relatively easy, has a plug-in for Unity and is compatible with IOS and Android devices.

To avoid risks inherent in my unfamiliarity with AR technology, I conducted extensive early testing to minimize the problems in later testing stages and to sufficiently test the accuracy of the Augmented Reality technology. Spending time learning the tools before embarking on the project itself helped me focus on the content of the game and make appropriate adjustments based on user testing. The first stage prototype followed a series of different design ideas that were eliminated after further research and analysis.

One idea that I considered and ultimately discarded was facial recognition technology; I explored the possibility of including a game mechanic in which the game's hardware recognizes the facial expressions of the user and the pet responds accordingly. For example, if the user looked sad, the pet might attempt to cheer him up. This was considered after looking into research that suggested that the emotional support provided by dogs towards their masters might improve the quality of life of children with Cerebral Palsy. However, this idea was discarded after observing how Cerebral Palsy affects facial expressions. In John's case, the muscles that control his mouth are affected by his CP; therefore, it would be difficult for the software to recognize sadness or frustration.

6.2.2 Stage 2: Physical object

The Cube

I wanted John to hold something physical that embodied the pet that he could carry with him at all times. I wanted to create a game that John could construct; this would help with his motor skills. Additionally, linking the virtual cube with a physical one is aesthetically pleasing and somehow tactile; it gives the feeling that the virtual cube is becoming real.

In the preliminary stages of the design process, the game design consisted of multiple cubes. The main character would inhabit the first cube, where the game would begin; the user could take care of the character by attaching and stacking different cubes. Each cube would represent a different interactive function. For example, one would contain food, while another would be an exercise area; by attaching the two cubes together, the user would allow the pet to move between the two. This was based on toy blocks, a popular toy among children; this design intended to transform them into an interactive version in which the child would be encouraged to use his hands to attach the cubes. However, after conducting some testing, problems began to arise; John's case of CP is too severe to hold multiple toy cubes without assistance. As such, I discarded this idea and began to consider using a single cube instead.

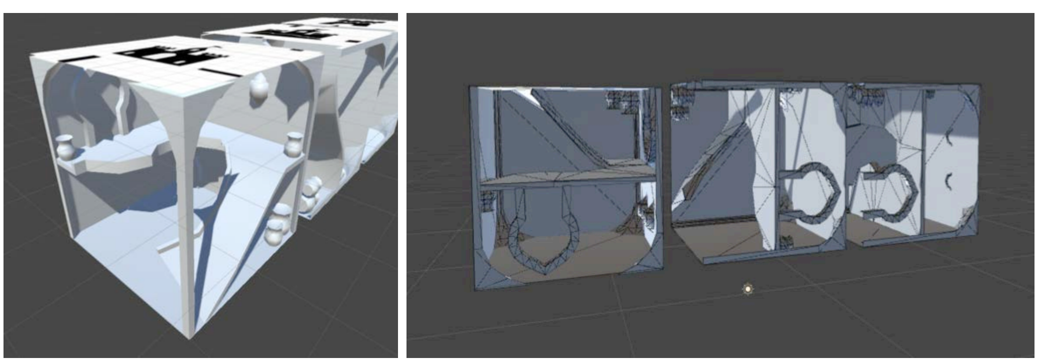

Figure 1: First cube prototype

The cube is designed as a natural and realistic input and platform for the game. Each side of the cube features a different target image that works as a bar code for the app to recognize when the built-in camera is activated on a tablet screen or a phone. Each target image on the cube represents a different angle of a virtual cube that the pet inhabits. When John rotates the physical cube, the virtual cube will rotate in the same way, allowing John to observe the pet inside of it through the screen. In order to make this possible, I duplicated the same cube six times in Unity and aligned each target image with the correct side. I experienced some technical issues at first, but eventually each side correlated with the correct image and the experience of rotating the cube became smooth.

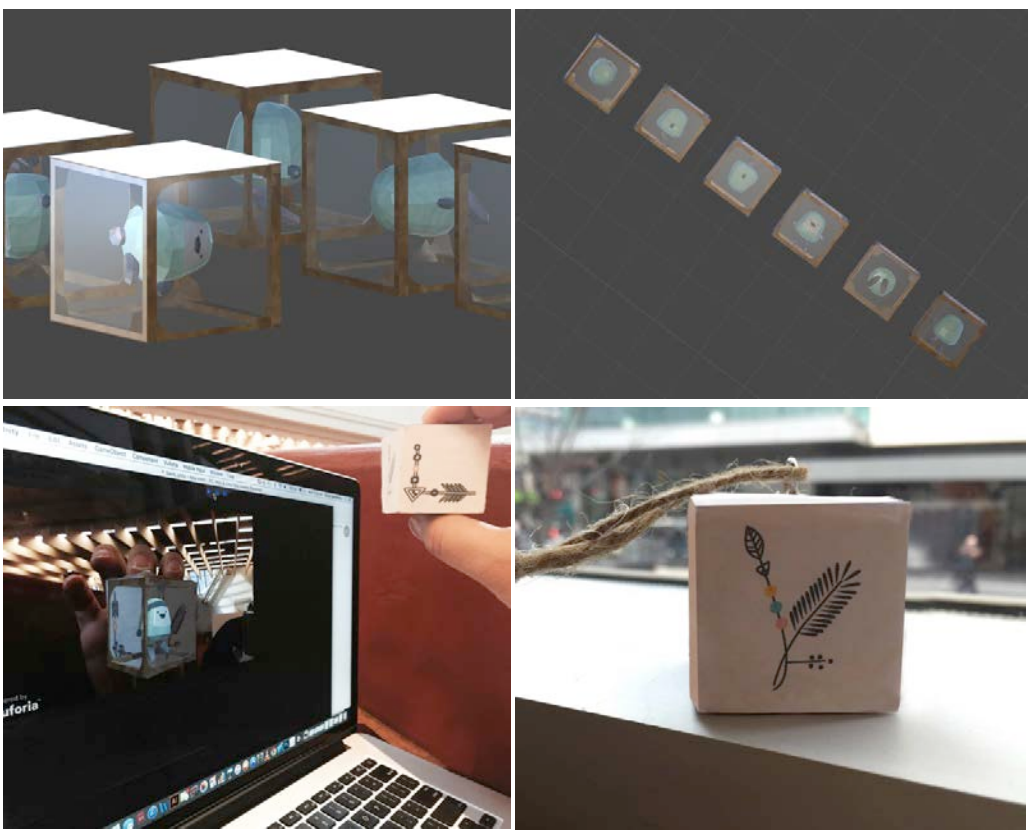

Figure 2: Second cube prototype

In this prototype, the app detects which target image is in front of the camera and projects the matching angle of the model onto it. If the marker recognition is not accurate, it is impossible to play; if it is weak, glitches might occur, frustrating John and affecting the testing of the game. In order to create a solid target, the target marker went through several iterations. During this process, I tested two of my colleagues to see if they were able to explore the virtual world and shift it without any problems. I explained the process without giving them a demonstration to observe the way they held the cube. The first tester experienced problems at first because her hand covered most of the active marker, but after a couple tries she began to hold the cube from the edge. The second tester had the same problem; additionally, she had trouble finding the front view of the model since the artwork on the physical cube doesn't differentiate between angles. I changed the target image and placed the artwork in the middle of the square so as to make it easier for the system to recognize the artwork. I chose not to differentiate between the sides of the cube because the experience of rotating the cube and exploring it is part of the gameplay experience.

Figure 3: A sample of different target images used in the design process

Next, I tested the size of the cube itself. I assessed the success of the cube based on how easy it was for John to hold and grab it and how fast the app would recognize the active target. The first size I tested was a 1x1 inch cube; this cube was too small and the app couldn't recognize the target image because it was fuzzy and unclear. This size was also too small to properly operate with one hand. Eventually I settled on a 1.5x1.5-inch cube, which was big enough for a clear target and small enough to be held comfortably by John. In future iterations, the cube will be attached to the wheelchair so that the virtual pet will always be with John, similar to owning a pet that follows his master around; it will also be easier for John to hold or touch the cube when he wants to play with it.

6.2.3 Stage 3: Input

Controller

The controller is a crucial element of game design; it should be intuitive and maneuverable, especially when designing games for children, who may become easily frustrated. This necessitated careful consideration of my user's unique strengths, weaknesses and needs. First, I examined a variety of existing assistive technologies for children with Cerebral Palsy and related physical disabilities. Next, I observed and interviewed the parents and the schoolteacher to identify the technologies that John currently uses. I resolved that my companion app must implement and contain familiar tools for two reasons: firstly, it allowed me to tap into an existing base of research on existing technologies for John, including input from his parents; secondly, by allowing John to interact in a new way using something that is familiar to him, I reduced the learning curve for the app. I also wanted the app to be as intuitive as possible to ensure ease of use and reduce frustration. In preparation for designing my app, I examined two technologies that John has been exposed to the most at school and at home.

Talk Assistive Technology Communicator

This tool helps children who are speech impaired learn expressive language; it gives them a voice, allowing them to interact through messages pre-recorded by others. Parents, teachers, and other children can record messages, songs, or jokes that can then be replayed at the touch of a switch. A single message can usually be up to twenty seconds long, but the time varies between devices. This tool is a push button device, which is a great option for people with physical impairments, who need a larger target area. John has had great success using this tool as well: when I visited him in his classroom for an observation session, the school had designated a specific time of day when they sat in a circle to listen to messages from their parents and siblings. John's first message was "good morning;" the second one was from his mom, saying that I would visit them today and introducing me. John had to push the button after each message; there were three messages in total. At the end of the day the kids in the classroom recorded some messages for John to listen to when he got home.

Push Button Switch

This tool is a low profile, brightly coloured switch that can be plugged in and attached to many devices. John uses this tool to navigate his computer; the switchboard performs the functions of the mouse and keyboard. It is highly pressure sensitive; children with spastic cerebral palsy have difficulty coordinating their movement since their muscles are always stiff or spastic, which means they have inflexible, erratic movements caused by abnormally high muscle tone. The pressure sensitivity of the switchboard allows John to successfully press the buttons even when he has trouble coordinating his movement. Observing how John used this tool with such ease, it was clear that this was an appropriate tool for my prototype because the input is simple. Most of the time, he uses one button, but on some occasions, he has been introduced to two. Having one button limits the types of interaction, which would eventually make the games tedious and boring for John. I began constructing an input system for the game in which two physical buttons would be connected through Wi-Fi with the game in the tablet. This was created using Unity, Arduino, and LightBlue Bean.

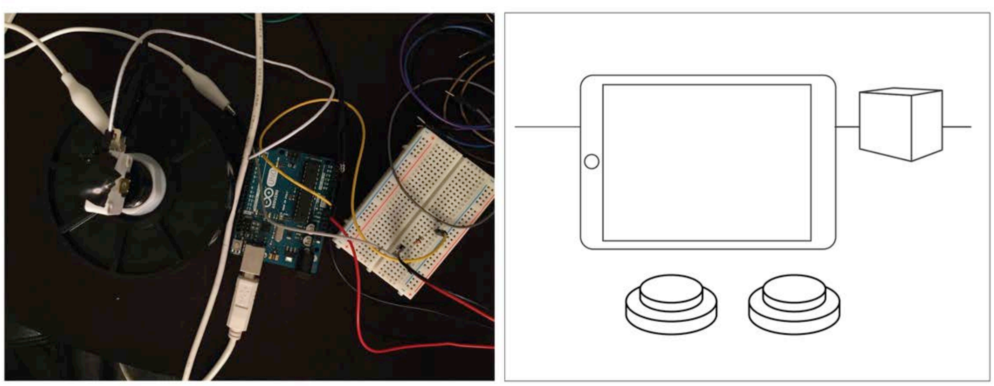

Figure 4: Building the pushbutton system

6.3 High fidelity prototype

This section of this thesis describes the second stage of the design process, in which I design the gameplay and test the high fidelity prototype of my project.

I will demonstrate the process of designing the game system, the input and the artistic elements that were implemented, and finally the user testing stage.

6.3.1 Stage 1: Game Guidelines

Conducting preliminary research, including a review of literature, observation of the user's behavior and an analysis of existing technologies helped me to identify critical points of focus for the game. During my interviews and observation sessions with John, I paid attention to the types of games and books he likes in order to learn more about his interests. I watched and recorded him playing with his parents, listening to music and watching his favorite cartoons to understand and analyze his body language and facial expressions, as well as his level of interest. This helped me understand and evaluate his likes and dislikes. While designing the game, I wanted to create an emotional connection between the pet and John. Additionally, I wanted to create an opportunity for John to fully experience a game with multiple functions and interesting animations with an easy interface based completely on his favorite things. One element I considered while designing the gameplay was that the game should be playable without the need to press buttons simultaneously or quickly, because it takes John around three seconds to react; in addition, because of the stiffness of his muscles, it takes some effort for him to move the hands. Below are some of the main guidelines I considered in the design process of the game in order to build a successful system for John:

Character: The game should create an emotional connection between the character and John in order to extend the period of play. The design of the character should be based on John's preferences, as he might lose interest if his specific needs are not taken into consideration. Additionally, the animation of the character must look natural, and similarly, the character's behavior should meet John's expectations. The success of this can be verified with user testing.

Frequent Rewards: John needs regular and direct feedback to keep his level of engagement as high as possible. The rewards should be received within a short time of playing so that John doesn't lose interest, but not so short that he loses the anticipatory factor of the game.

Game Pace: The game should be slow-paced in order to give John time to make decisions and to avoid frustration or feelings of inadequacy or inability. The character and other objects should be aesthetically simple and uncluttered. The environment in the game should be neat and organized so that John can focus on the virtual pet character.

Functions: The game should not have more than four functions to limit the risk of confusion or complication for John. Offering variable colors and different illustrations for each button allows John to easily differentiate between the various functions.

Level: The game should be easily navigable to fit John's cognitive ability. In the first stages, the game will be directed by a facilitator. This will change when John gains the confidence necessary to play the game independently.

Music: The game should include music and sound effects, as John enjoys music and it will help him become more engaged.

6.3.2 Stage 2: Character and Animation

In order to maintain John's interest, I created three different character designs. The first character design was created before meeting John and upon the first meeting, I tested his reaction. He showed little interest. After observing him and learning about his tastes and interests, I realized that it was clearly not the right fit. The colors had to be bright and the character had to be more strong and fierce. Therefore, I decided to combine his two favorite things: superheroes and dinosaurs. Creating the character was a challenge, as I have little experience in animation. I considered how the character would move and what kinds of interactions would be possible. I also wanted to create a character that would mimic the movement of the human body. Using Augmented Reality to create a character that could fly in the physical space shown by the camera was promising, as it would make the character seem more real. The character was designed to be able to move around the cube and also to fly over it. Before I created the animation I decided which types of functions to use. After conducting research on the types of interactions that occur when taking care of a pet, I settled on two chores, which are the main game mechanics that require human intervention.

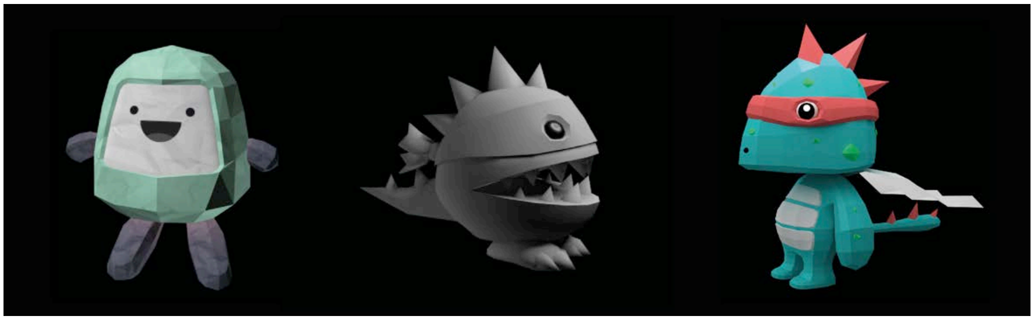

Figure 5: design evolution

6.3.3 Stage 3: Gameplay

Controlling the character in the game is straightforward; there are two different inputs. The first mode, which involves pressing buttons, is intended for John to increase the use of his hands. This will help the repetition of hand movements as John explores the game. The second mode of input is through his voice; at certain points during the game, John will be asked to use his voice to activate an action. This technology will motivate John to work on his speaking. Since John can only produce sounds with no clear distinctions between words, I chose to use sound recognition instead of voice recognition.

The game will start with the front camera activated in order for John, with the help of his parents, to explore the cube and watch the dinosaur. He can bring the cube closer to the camera to get a closer look at the dinosaur. Next, the cube will be placed behind the tablet on the table of his wheelchair. The tablet will be attached to the wheelchair with a mount. This will let John adjust the screen to his preferred position based on his hand and arm length. When the cube is placed behind the camera a button will appear on the screen. This button transforms the cube, releases the character from the cube, and begins the game. John will be presented with two buttons on each side of the screen with different colors. The first button will be responsible for feeding the character. John will have to feed the dinosaur four times before he receives a reward; in this case, the dinosaur will be fed until it's happy, full, and eventually dances. There will be an energy bar to indicate how much more he needs to feed the dinosaur before he can see the reward. This will motivate him to press the buttons. The second button is responsible for walking the dinosaur; as a reward, the dinosaur will fly around. Another animation is the dinosaur holding his ear as if he can hear something; this will be activated with sound.

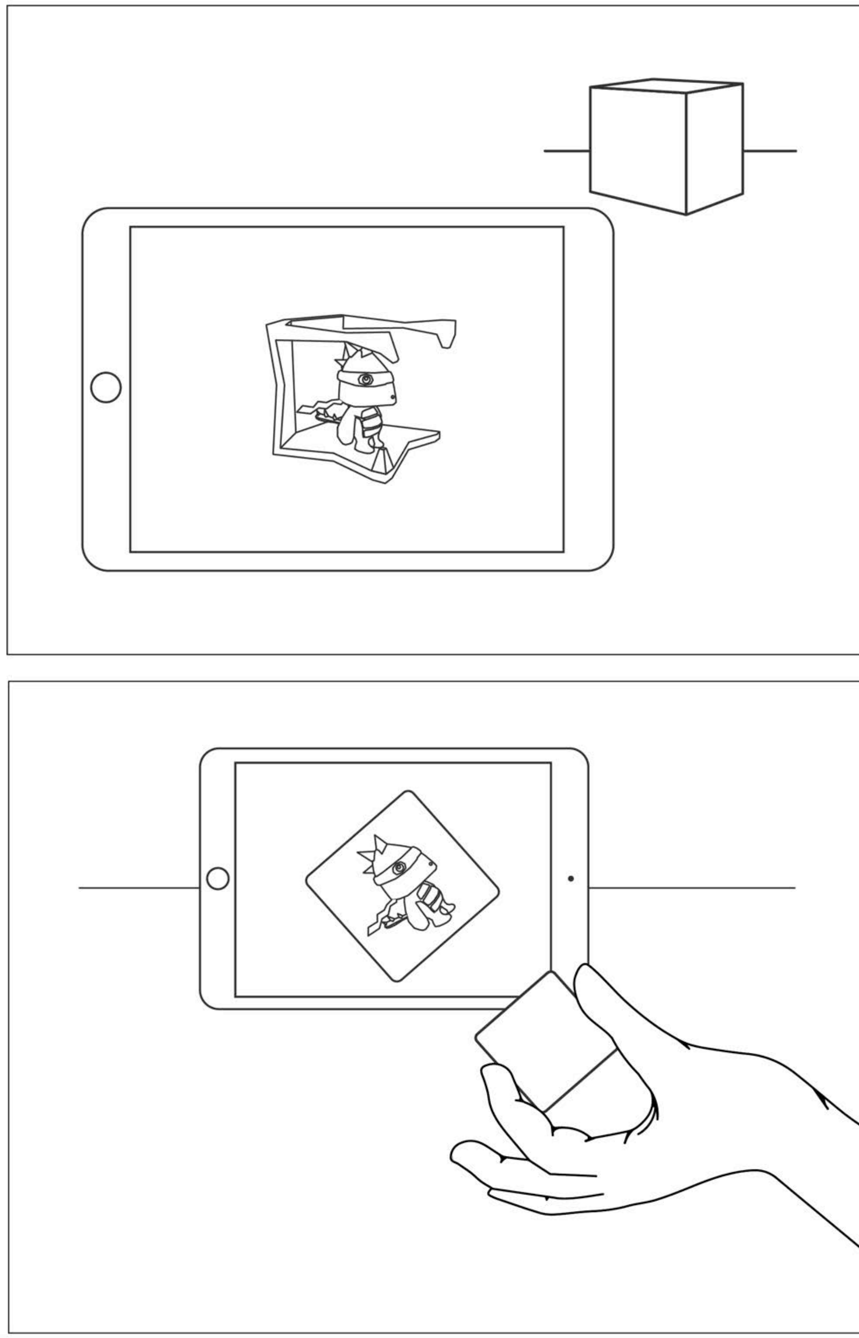

Figure 6: Demonstration of the different positions of the cube

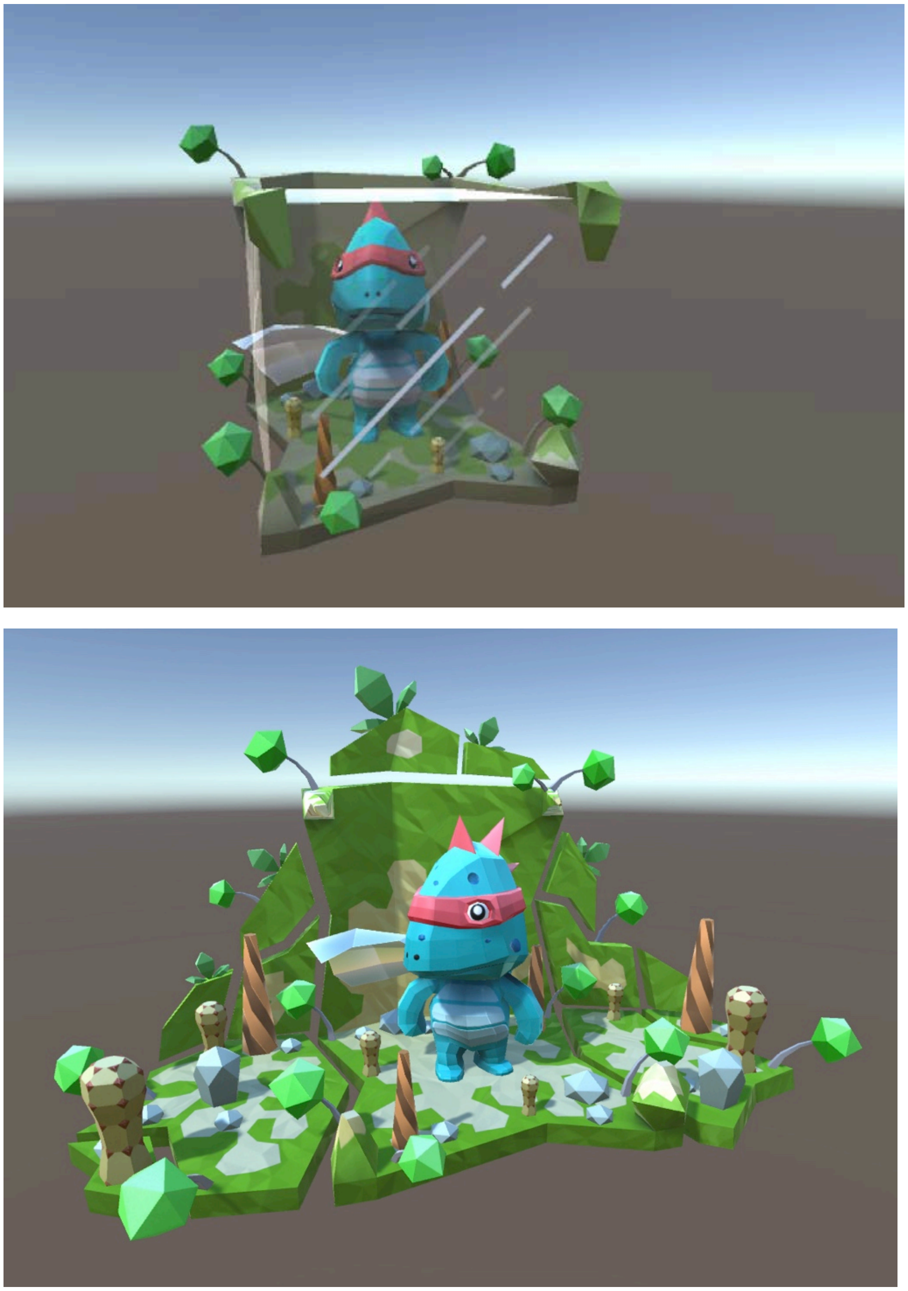

Figure 7: The transformation of the cube

6.3.4 Stage 4: User Testing

Play session

In order to test the effectiveness of the game, I conducted a user testing session. This was not the first test for the game, but it was the first play session in which the game was fully functional. The session began with a demonstration with John's mother. I wanted his mother to facilitate the game for a couple of reasons: first, John is likely to be comfortable with his mother, especially since he needs encouragement throughout the game and his mother knows him best; second, this game is intended to be played at home; naturally, the parents will facilitate it.

In the days before the test while I was working on connecting the pushbuttons to the game, I considered making a digital screen touch button, since an iPad touchscreen is so sensitive that it does not require John to use much strength while using it. Also, a touchscreen tablet is more compact than a separate pushbutton; it would be easier to play the game outside of the home without any separate devices.

I was aware that John had played some games on an iPad, but it was not easy for him to play, as some games require him to drag items, which is difficult for him. I decided to create two large buttons on the screen and to give them two distinct colors so as to make them similar to the physical pushbutton that he is familiar with. When demonstrating the game with his mother, she told me that she honestly did not know whether the game would work or not with the touchscreen.

During the first play session, John was unwell—he had a cold. His mother warned me before we started, telling me that he might not perform as well as I expected. However, it was a good chance for me to test the game when he was likely to be less interested because if he performed well in those conditions, the game would likely be a success when he was more energetic. I experienced some technical difficulties with the wheelchair mount; in the end, we held the iPad while John played the game. This was an inconvenient process but did not affect the gameplay. John was at first disinterested as we struggled with the setting, but as soon he saw the character on the screen and his mother started to move the cube around for him to see all the sides of the cube, he became calm and focused. I told the mother to use phrases such as "look at the dinosaur", "Do you want to feed him? He's hungry," and "he needs a walk". I wanted to create a bond between John and the character.

After setting up the game and introducing it to John, we began the play session. John's mother explained the game to him; at first, she had to hold his hand to make him touch the buttons. After this, she asked him to touch the pushbutton and to our surprise, he started to push the buttons and play the game.

Overall, the experience was successful despite John having a cold; in fact, during the 20 minutes, he hit the buttons more times than I anticipated. The fact that he kept trying to hit the buttons when his mother and I were having a conversation, despite the fact that no one was encouraging him, demonstrated the potential of the game. However, the play session revealed some problems that were later modified. These will be explained in detail in the next section.

Challenges and Iterations

The first glitch occurred early at the beginning of the testing session; John accidently closed the app and shifted to the main screen as he was trying to push the button. We rectified this issue by using the guided access feature to restrict access to the keyboard and to other apps, so as to enable John to drag his hand over the screen to push the button without getting frustrated every time the app window closed. The second problem was that the buttons were too small for John to easily press. However, enlarging the buttons would have obfuscated the play area. I solved this problem by activating the area around the buttons. This meant that that John did not have to aim exactly on the button; if he hit the area around it, the button would still respond.

The game had two different inputs: one required him to use his hand to play the game, while the other required him to use his voice. During the test, every time John used his voice, the dinosaur held its ears as if it could hear something. This was not successful because throughout the game, John's mother had to encourage him and explain the game, so the animation lost its meaning and had no impact on John, making him unmotivated to speak. When I spoke with his mother after the game, she suggested that I use the same format they use when they want him to speak, in which they encourage him by telling him "use your voice to say yes, if you want…" After the play session, I modified the sound recognition mechanics; I made it necessary for John to use his voice to get the character out of the cube and activate the game; the character prompts John by telling him to use his voice if he wants to start the game.telling him to use his words and say yes if he wants to start the game.

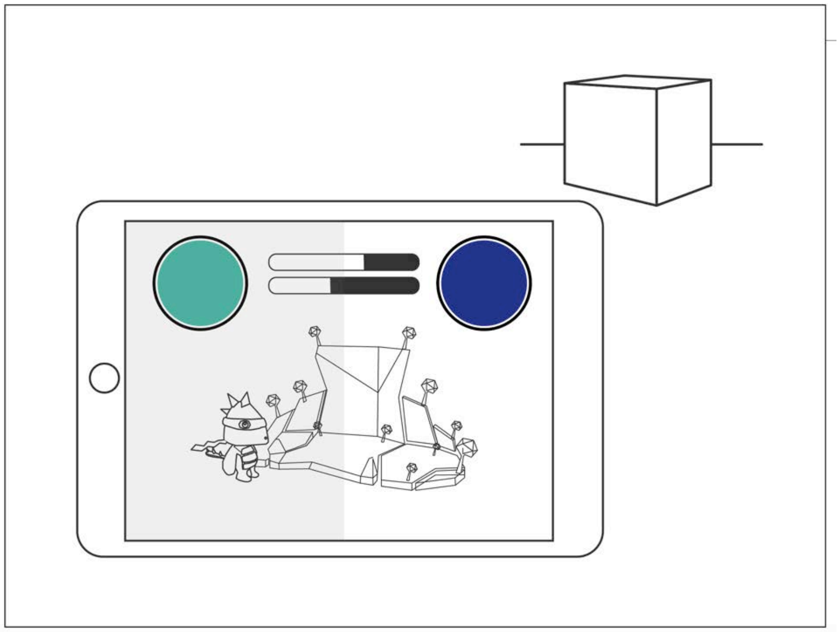

Figure 8: The activation area around the buttons bigger

Figure 9: Animation for the voice activation

The animations were based on John's interests so as to make him pay attention and motivate him to play the game. However, his mother suggested that I minimize the artwork of the open world behind the character. Since the colors of the world and the character were bright and there were a lot of elements on the open cube, it was a bit overwhelming for John. I modified the design so that John's focus would be on the character and its animations.

Figure 10: The open world before the modifications

7 Conclusion

7.1 Reflections

Following my preliminary research on assistive technologies for children with CP, the main objective of this project became to investigate the use of video game consoles as a tool for the rehabilitation of John, a six-year-old child living in Toronto, Canada, who suffers from Spastic Quadriplegia (CP). This thesis examined previously published research and collected evidence for the application of assistive technology in the rehabilitation of children with Cerebral Palsy and the advantages of pet therapy. The first stage of research involved a series of interviews with a male child in Saudi Arabia with Spastic Quadriplegia and his parents. During the discovery stage, I collected data and analyzed extant research on the challenges and methods of communication for children with Cerebral Palsy. This stage elucidated for me the nuancd lived experiences of these children, with which I was not formerly familiar, and might not have otherwise realized.

Virtual Companion is a play experience that motivates the user by mobilizing gameplay for rehabilitation purposes; on a broader scale, the project provides children with Cerebral Palsy with a tool to further engage with the physical world around them. The purpose of this prototype was to examine whether caring for a virtual animal within an augmented reality framework would help motivate and encourage the child to participate more in the game. The input for the game was designed in consideration of the motor challenges affected by Cerebral Palsy physical therapy and based on John's current treatment. The system of the game helps to reduce muscle stiffness in John's hands by engaging him in an entertaining and immersive environment in which he must move his hands. John has limited mobility and experiences difficulty performing motor tasks, such as holding an object or pointing his finger. Using the Virtual Companion app, John can interact with a virtual pet using augmented reality and animations. Since there are multiple elements involved in the game design, user testing was crucial in the development stage. The project involved several research phases and methods and numerous prototypes so as to create a product specifically suited to John's needs.

7.2 Main Findings

There is a large body of existing assistive technologies for people with mental and physical disabilities. However, "disability" is a widely diverse term that encompasses a spectrum of disorders and differ-abilities; even within the same disorder, two people might face vastly different challenges. For instance, one technology may work well with another child who suffers from Spastic Quadriplegia, but this does not mean that it will work for John. Every child is a different case with different restraints and limitations. As such, I specifically designed this thesis project for John's rehabilitation, based on his needs and interests. Below are the findings from my explorations.

Firstly, the results of the play session showed promising potential for the use of pets in enhancing motivation. John's activities and the increased use of his hands were significant. However, this thesis could not confirm whether or not

John has fully grasped the idea of Augmented Reality. In order to evaluate the concept of the cube and to see whether John is able to understand the correlation between the physical cube and the character, further user testing is needed.

Secondly, the pushbutton is a rather antiquated mode of interaction compared to newer technologies and game designs, but for John, it is the only gesture he is accustomed to. Having the buttons on the touch screen instead of physical buttons proved to be very effective and surprisingly intuitive. After basing the game gestures on what is familiar to John, the next step in future iterations of this project will be to test other types of hand gestures, such as swiping. This might reveal more intuitive gestures that might help John further benefit from the game.

Lastly, observation sessions are extremely important, as oftentimes, interviews with parents and specialists are not sufficient for the researcher to grasp the user's situation. In my case, while observing John, I watched him interact with others, learned about his tastes and observed his body language, which was crucial in the creation of the game and analysis of his reactions.

7.3 Challenges

The biggest challenge for this project was finding a user for my research. Since I am an internationals student with few connections in Canada, I did not know how or where to start. I was fortunate enough to be introduced to John and his lovely parents through a classmate. However, his case was more severe and he had another type of Cerebral Palsy than that of my initial interviewee in Saudi

Arabia, with whom I began to define a direction for my thesis. After meeting John, I had to discard several ideas that I had previously developed and start again. Having more time with my user would have helped develop the game even further than it is right now and I would have had a chance to experiment with other gestures.

Another challenge was my unfamiliarity with the technologies involved, namely Unity and Augmented Reality. In order to mitigate this issue, I spent a considerable amount of my time researching and experimenting with the tools to understand their limitations and capabilities. Even though I studied Augmented Reality technologies for most of the year, I still feel like this technology has yet more to offer and is yet to be fully utilized in my game.

I also had some difficulty acclimating to an observatory role during my observation sessions with John and his family. The atmosphere of the first observation session was intimidating; I did not want to interfere with the natural setting, and yet I was still a stranger to John and his parents, making observation without interference naturally more difficult. However, after the first time and after reading guidelines regarding how to conduct a successful observation session, I became more confident and conducted the observation sessions sucessfully.

7.4 Future Steps

The pushbutton was useful as an early input method, as it is already familiar to John; however, its simplicity limits its potential for innovation and challenge, and in future steps I plan to experiment more with other gestures and with the multi-touch technology provided by the touch screen; hopefully, I will discover a control scheme more intuitive for John. I will conduct more play sessions to refine the game and to look for other possible interactive features to enrich the experience for John.

Since the design stage of the game, there have been several features that I wanted to implement; however, given the timeframe of the project, I was unable to use them. Below are two examples of ideas and possible directions for the game that were considered for future implementations:

Smart Terrain

This feature is offered in Vuforia and allows for a new level of engagement in Augmented Reality games by enabling the user to rebuild and enhance the surface of the physical environment. For a game experience, it begins by scanning and detecting the objects present within the viewfinder of the camera, then it begins to build or grow over the surface of the identified objects, allowing the game characters to jump over objects or run in between them. I wanted to implement this technology because children with mobility issues may find the interface freeing, allowing them to explore and navigate through space through their characters. Additionally, it is technically simple to mount a tablet and camera on a wheelchair. Implementing this function turned out to be too complicated for my minimal experience in Augmented Reality technologies. Additionally, according to several developers with whom I spoke about

Augmented Reality, this program still has some glitches and is more appropriate for game demos at the current time.

Eye-tracking

In the preliminary stages of the research, eye tracking was considered as a possible input mechanic for the game. This was suggested by the parents, who wanted a more affordable alternative to an eye-tracking device for their child to practice with. They wanted to use this technique since sight is one of John's strongest senses. However, it was abandoned as the research shifted to focus on helping the child with tools familiar to him in order to reduce the learning curve and to increase the movement of his hands. I plan to include this feature in the future along with the other different input systems to offer a wider range of interaction.

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9 Appendix A: Companion App Design Process

Figure 11 Kijo character

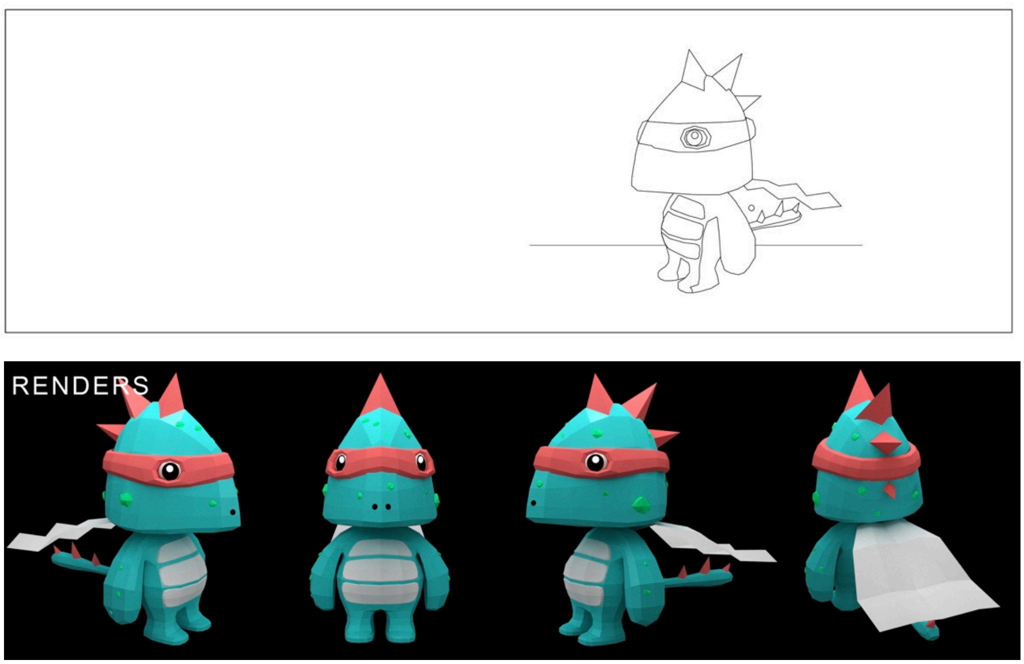


Figure 12 Kijo character design renders

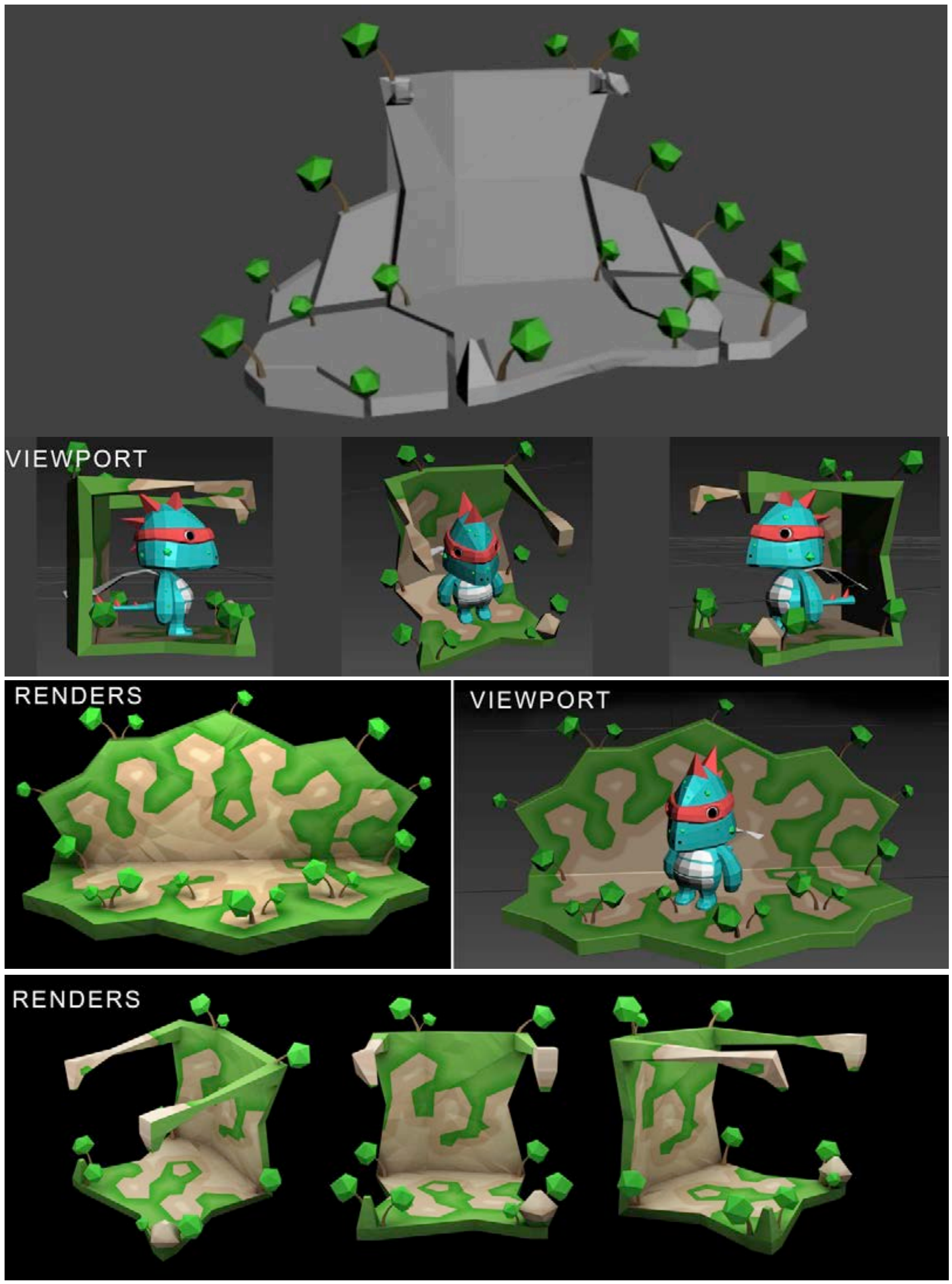


Figure 13 Game design renders

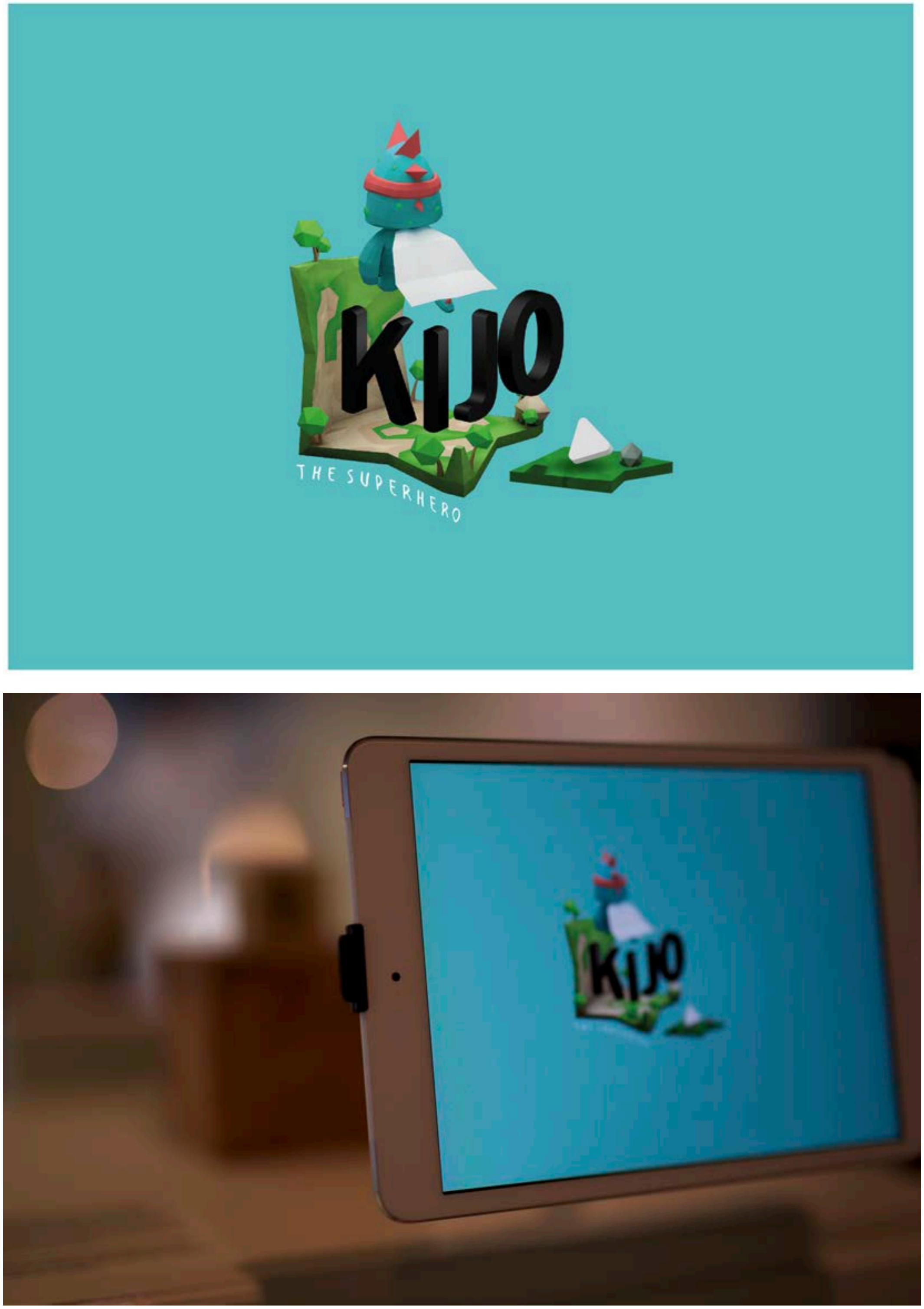


Figure 14 Companion app first page

Figure 15 Final cube design

Figure 16 Virtual companion app after the transformation

Figure 17 Virtual companion app before the transformation

Figure 18 Holding the three different characters

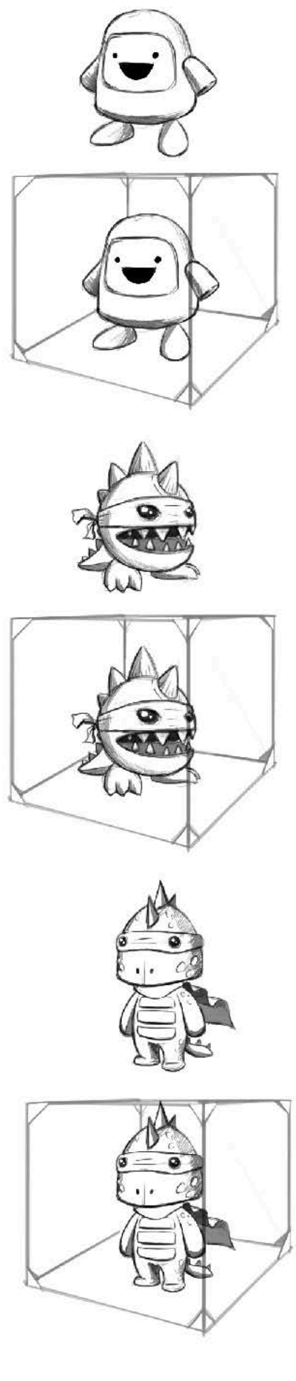


Figure 19 Sketches of the three different characters

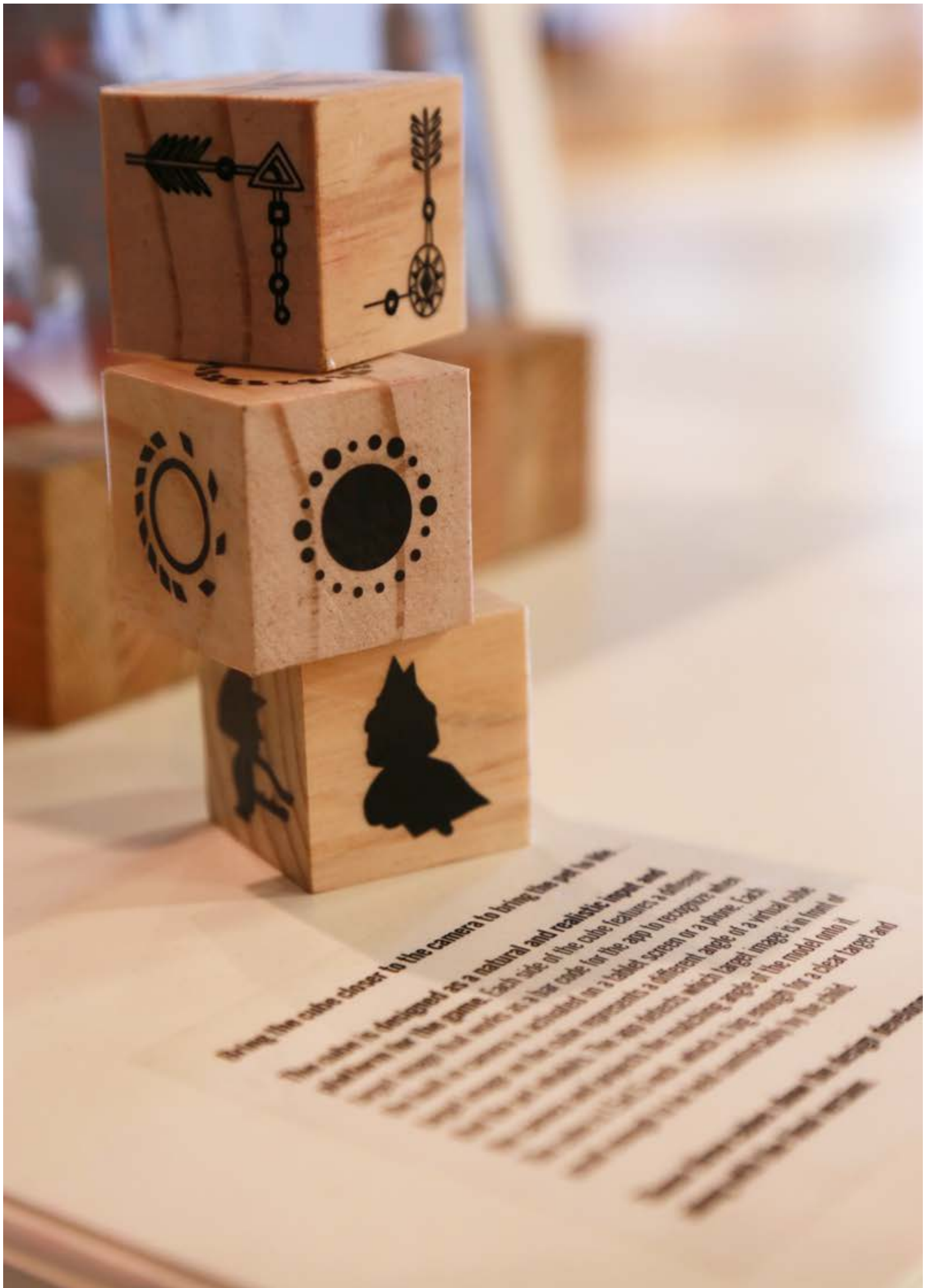


Figure 20 Three different cubes with different characters

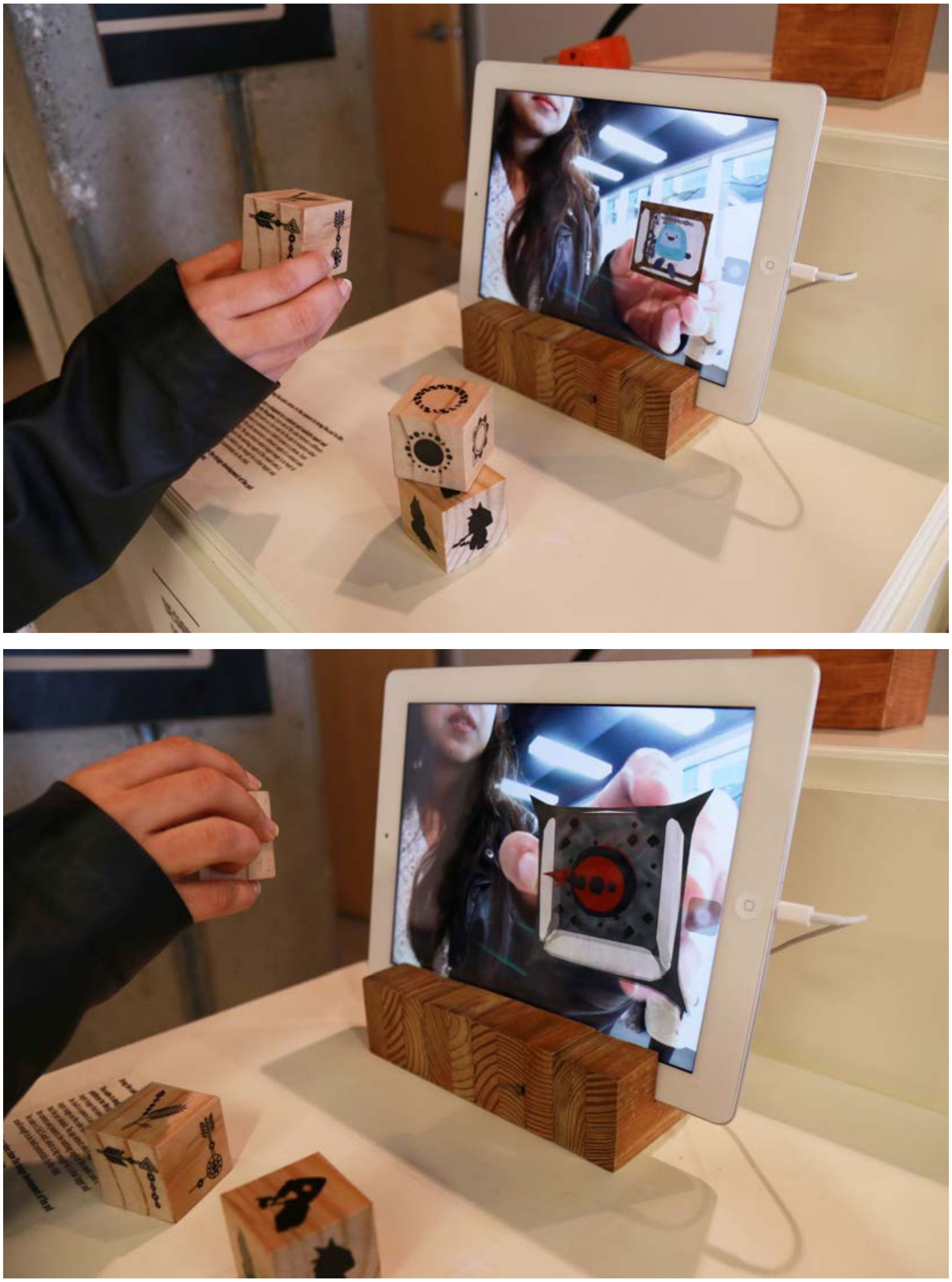
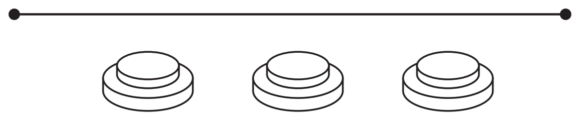


Figure 21 Previous characters designs for prior cubes

Figure 22 Companion app final character cube: Kijo

Figure 23 Virtual companion app poster

Arduino Code for the three buttons



```
const int button0_pin = 2;
const int button1_pin = 3;
const int button2_pin = 4;
int button0_state = 0;
int button1_state = 0;
int button2_state = 0;

void setup() {
  pinMode(button0_pin, INPUT);
  pinMode(button1_pin, INPUT);
  pinMode(button2_pin, INPUT);
}

void loop() {
  button0_state = digitalRead(button0_pin);
  button1_state = digitalRead(button1_pin);
  button2_state = digitalRead(button2_pin);

//BUTTON 0 CHECK
  if (button0_state == 1) {

  } else {

  }

//BUTTON 1 CHECK
  if (button1_state == 1) {

  } else {

  }

//BUTTON 2 CHECK
  if (button2_state == 1) {

  } else {

  }
}
```

Figure 24 Arduino code for the three physical buttons