**Improving Low-Cost Entertainment Options with a Focus on Sensory Stimulation and Social Interaction for Children with Cerebral Palsy**

Abstract

This request for proposal asks for a design that improves entertainment options for children with cerebral palsy, with an emphasis on sensory stimulation and social interaction. Cerebral palsy is a congenital, non-progressive brain condition that affects muscle tone and motor coordination. This condition affects 1 in 3 premature babies. Although these children can share the same mental capacity and growth as non-impaired children [1], their physical limitations can restrict the methods in which they play. Hence, adaptive play methods have been introduced and have become widely recognized for allowing children with cerebral palsy to experience a fun, imaginative, and stimulating play session. If a child has motor impairments, modifying the toy with which they are interacting or changing the method in which they play can allow them to participate and have more control over their play [2]. Methods of adaptive play can include specialized toys, interactive games, or activities such as therapeutic swimming. Studies suggest that adaptive play can benefit a child’s well-being through sensory stimulation and social interaction [3]. Research and stakeholder meetings indicate that sensory stimulation is necessary for the growth and development of children’s physical, mental, and emotional welfare [4]. Furthermore, social interactions are crucial to a child’s sense of self and development.

This request for proposal will focus on improving and further developing adaptive play for children with physical limitations as a result of cerebral palsy. A cost-efficient solution is required due to the financial stress of families with children who have cerebral palsy [5]. In fact, the average health care expenditures of a special needs child is around 3 times higher than a child without special health conditions [6]. The proposed design will allow children with cerebral palsy to experience the benefits of play in a safe, engaging, and adaptive environment.

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1. Introduction

This request for proposal frames an engineering problem in the community of children with cerebral palsy (CP) and the importance of having toys or activities for adaptive play. Cerebral palsy is a congenital, non-progressive condition affecting posture, body movement, muscle tone, and coordination [1]. The current entertainment options for children with CP are inadequate due to the lack of adaptive, low-cost sensory stimulation and opportunity for social interaction among their peers.

Phrases commonly used throughout are:

- **Social Interaction**: the dynamic chain of actions involving two or more mutually aware individuals in which thoughts, experiences, and other information are shared.
- **Sensory Stimulation**: nerve impulses resulting from the excitation of the sensory organs that can improve the child’s sight, hearing, olfaction, touch, taste, kinesthesia, and balance.
- **Adaptive Play**: the entertainment of an individual through alternative means because of their physical inability to entertain themselves in the conventional sense. Mobility and sensory disabilities serve as a barrier to spontaneity in play, though changing the shape of the toy, position of the child, or way an activity is carried out improves the child’s control of play [2].

A study concerning pretend play of children with cerebral palsy showed that affected children had diminished play ability when playing with conventional toys, and 65% of the children showed deficiencies in their play, such as their subnormal ability to spontaneously initiate pretend play. However, by giving adaptive toys to children with CP, the children had increased positive emotion and imaginative expression when playing [3]. Furthermore, increased play skills showed improved cognitive and affective play processes [2].

Children with CP also seem to adapt the way in which they perform activities while playing, such as taking alternative routes to the top of a playscape, to match their physical capabilities. By doing this, they establish social roles for themselves among their non-physically impaired peers through play [4].

However, there is a range of severities and classifications of cerebral palsy, such as spastic and dyskinetic, and children with CP are affected in different areas of their bodies [1]. According to Megan Stuart, Program Assistant of Educational and Recreational Services at the Ontario Federation for Cerebral Palsy (OFCP) (see Appendix A), each toy or activity for each child should consider their individual needs. As a result, accessible toys for children with CP have a very high cost because they are not mass manufactured. Therefore, there is a lack of universally acceptable adaptive toys and activities.

This request for proposal will provide more information on this community, as well as its specific needs. Furthermore, potential stakeholders will be discussed, the engineering problem will be stated, and requirements for this engineering problem will be outlined. Finally, several reference designs will be critiqued with the previously mentioned requirements to show how current solutions to this problem are inadequate.
2. Community

2.1 Children with Cerebral Palsy

The community of interest in this report are children between the ages of 4-8 who have cerebral palsy. These children range from Level III-V on the Gross Motor Function Classification System for Cerebral Palsy (GMFCS) (See Section 2.3) [5]. The age range was selected because students begin school at the age of 4. Therefore, the information gathering process is made easier because these students attend a formal institution and there are more opportunities for social interaction. Furthermore, early childhood is defined for children from birth to age 8 [6].

2.2 What is Cerebral Palsy?

In 2007, experts in the field of cerebral palsy came together to improve the international definition of cerebral palsy, which is stated as follows [7]:

“Cerebral palsy describes 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. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy, and by secondary musculoskeletal problems.”

Cerebral palsy is the most common motor disability in children (See Appendix A.7) [9]. As stated by the Ontario Federation of Cerebral Palsy, over 50 000 Canadians live with CP, and one in every 500 children is born with it [1]. Furthermore, although CP is often accompanied by cognitive impairments, there are cases of CP where cognitive impairments are not observed as seen in Figure 1 (See Appendix A.1). According to Health in Motion Rehabilitation Clinic (See Appendix A.2), children with motor impairments still enjoy playing, just like any other child. However, due to their inability to interact with their environment like other children, playing is usually more challenging [3]. There is currently no cure for this condition.
2.3 Cerebral Palsy Classification

There are several different classifications of CP, each emphasizing a certain trait. In this report, GMFCS will be used as stakeholder interaction suggests it is the most widely used classification system (See Appendix A.8). It is a 5-level system based on mobility limitations [5].

Figure 2. Description of the different levels of CP [10]

These reports focuses on a design for level III and higher because most toys on the market are not accessible for children with this level of CP since they require the use of an assistive mobility device, limiting potential for play (See Appendix A).
3. Opportunity for Improvement

There are four key aspects that are involved in the modification of the current situation to create better entertainment options for children with cerebral palsy: development through play, social interaction, sensory stimulation, and cost-effectiveness.

3.1 Development through Play

When children engage in play, they have an opportunity to express their emotions, improving their self-regulation of emotions later in life. Furthermore, play during a child’s development increases the amount of affective expression and decreases the amount of negative expression [2]. In particular, pretend play teaches children the concept of “theory of mind,” where one may have different thoughts and opinions than others. It also allows children to take on varying social roles through role-playing in multiple perspectives, which improves their communication and problem solving skills, as well as their ability to empathize with others [11].

With unaltered toys and activities, typical play, such as pretending to have a doll drink from a bottle, requires fine motor skills to navigate the activity. This is difficult and perhaps impossible for some children with cerebral palsy [2]. Typically, these toys are altered by the addition of Velcro strips and grasping aids, and children with cerebral palsy are placed in active learning positions, such as sitting at a 90° angle [2][12]. Adapting toys and activities used by children with CP allows for simpler instruction, improving the quality of their play as well as their development [2] by enhancing participation and engagement of a child, thereby leading to an exciting, imaginative, and stimulating playtime.

3.2 Social Interaction during Play

Individuals with cerebral palsy face social isolation due to their physical impairments, which can take the form of unclear speech, stiff muscles, and muscle weakness. However, this social exclusion of adult individuals with CP could potentially be overcome through bonding with others (with or without CP) during their childhood through play. Undirected play allows children to improve their negotiation, sharing, self-advocacy skills, and most importantly, their ability to resolve conflicts [13]. However, for children with motor impairments the form of undirected play may need to be adapted and adjusted through modified equipment, changed processes and assistive technologies [14]. It is plausible that social bonding through play will allow children with CP to form and retain a positive social role in the culture of their impaired and unimpaired peers [4]. Children with CP are limited in the types and depth of play in which they are able to engage and thus need an alternative outlet through which they can entertain themselves (See Appendix A.1).

3.3 Sensory Stimulation; an effective treatment

Sensory integration is a type of therapy designed for children who have problems with processing sensory input, especially external stimuli, including: balance and stability, tactile senses, hand-eye coordination, sense of orientation in space, and visual perception.
Sensory integration therapy is implemented through sensory stimulation, which improves learning abilities, social interactions, and the emotional well-being of the child and decreases frustration and negative reactions [15]. Activities involve engaging the senses, such as playing music, cooking, and dancing. Based on an interview with Health in Motion, sensory stimulation helps children become more independent and have better control of their motor processes (See Appendix A.2).

3.4 Cost Effectiveness as a Priority

According to the 2000 Medical Expenditure Panel Survey, the average health care expenditures of a child with special health care needs is around 3 times the normal health care expenditures [16]. Although the government covers parts of these expenses, many families find themselves with decreased disposable income [17]. In our interview with the OFCP, it was brought to our attention that families who have children with CP experience financial difficulty surrounding the purchase of toys (See Appendix A.1). Therefore, affordability is one of the most important design objectives for this project. In addition, in our interview with Vicki Komisar, a graduate student at Toronto Rehabilitation Institute, she stated that her view is that “most children’s rehabilitation products are overpriced” (See Appendix A.6).

4. The Engineering Problem

The current entertainment choices for children with cerebral palsy are inadequate because of the lack of low cost, accessible options that stimulate the senses and provide opportunities for social interaction among peers.

A significant challenge is that most toys designed for children with cerebral palsy require the use of fine motor skills and muscular control, as seen from a notable online store for CP toys, fatbraintoy.com [18]. In the store, 38 out of the 42 showcased toys for children with CP require the child to throw, catch, grasp, twist, squeeze and/or knead. However, individuals of all 5 most common types of CP have limited or no control in at least one arm or hand. [1]. This demonstrates that the current toys on the market do not fully reflect the needs or abilities of children with CP. This was demonstrated in interviews with research scientists (See Appendix A); they were all concerned with improving motor skills of children with CP, rather than entertainment. Fanny Hotze, a researcher focusing on entertainment and fun through sensory stimulation along with the improvement of motor skills, mentioned that there is a lack of low cost universally accessible designs in the market for children with CP (See Appendix A.9).

So far, innovations such as the Virtual Music Instrument (See Section 8.4) are very accessible; children with a wide variety of impairments are still able to participate. They also focus on sensory rather than motor interaction with the children, but are very expensive. Since children with CP are in need of many motor aids and therapy, most middle and low income families do not have sufficient disposable income to spend on most kinds of toys and sports equipment designed to improve adaptive play.

There is a need for accessible entertainment options for children with impairments such as cerebral palsy that stimulate their senses and encourage social interaction without being too costly for the average household.
5. Stakeholders

After talking to many different stakeholders and doing our own preliminary research, these stakeholders below were chosen to be of most importance in this report. The following are ranked in order of who benefits the most from the project:

5.1 Children with Cerebral Palsy

- They are the most direct stakeholders, as they represent the individuals for whom the solution is primarily designed (See Section 2.3).
- They will play with the design, with the hope being that they benefit from sensory stimulation, participation, and effective use of the design which must also be accessible, safe, and hygienic.

5.2 Parents/Guardians/Caregivers

- These are the people with legal custody of and/or provide care for the child with CP.
- It is important to note that the parents/guardians/caregivers will most likely be the individuals to implement the design to interact and communicate with the child. They prefer to have a design which is cost-efficient yet beneficial for the development of their child. Therefore, minimizing cost is crucial because families with impaired children are already financially stressed [17].

5.3 Organizations/Facilities which Support Children with Disabilities

In our research thus far, we have encountered several institutions within the GTA specializing in activities surrounding children with motor impairments, including cerebral palsy. Three institutions are shown below, ordered in terms of stake in the project:

1. Bloorview School Authority — This school specifically caters to students with special needs, including cerebral palsy (See Appendix A.8). Games and interactive play are an important part of facilitating the social and mental growth of its students [14]. Through use of the design, the schoolchildren will experience a friendly, social environment by which they can play, learn and develop (See Section 3.2). In a populated environment such as a school where it is highly likely that more than one individual will use the design, it is important that the design remains safe and hygienic (See Appendix A.6).

2. Ontario Federation for Cerebral Palsy — this organization focuses on “assisting persons with cerebral palsy with funding for equipment, … and recreational activities” [19]. As such, this organization is instrumental in distributing and advocating new technologies to the cerebral palsy community. They need to raise awareness and maintain a healthy relationship with their community, which can be achieved through implementation of a novel or improved design.
3. Variety Village — this facility provides programs to a wide variety of people, including those with cerebral palsy. They improve the lives of their clients “through inclusive and integrated hands-on activities like adapted games,” [20] which promote acceptance and entertainment for children with CP. This corresponds with the purpose of this proposal. Variety Village benefits from the design because they would like to have more opportunities for customers to engage in a wider range of physical activities (See Appendix A.2).

5.4 Occupational Therapists

To provide beneficial therapy to children with motor disabilities, many therapists use engaging games to stimulate mental and physical improvement [14]. An improved design will help the therapist communicate with the child and the child experience an enjoyable and successful session. Therefore, a design that allows for participation will improve the bond between therapist and child.

5.5 Hospitals

Hospitals, such as SickKids and Holland Bloorview, provide therapy and specialized care for children with cerebral palsy. Medical personnel frequently use play as a form of rehabilitation (See Appendix A.3, A.7, and A.9). Hence, they require a design that stimulates the sense of a child undergoing rehabilitation therapy, and a design that is sanitary as it is a hospital.

While having a design specifically for children with cerebral palsy is the focus of this RFP, it would be a benefit if the design is also applicable to children without CP as this would allow for more social interaction among children with CP and their peers who do not have this condition. As well, allowing more children to be able to use the design satisfies the ambition of creating a universal design. For more information on stakeholders and some of their opinions, see Appendix A.

6. Engineering Requirements

This section outlines the requirements that the design should satisfy. The order of the following list of requirements is based upon their relative importance (See Appendix B).

6.1 Objectives

6.1.1 High Order Objectives

- Improve social interaction and sensory stimulation of children with cerebral palsy of level III-V (as per GMFCS) through adaptive play
- Create a cost-effective design which can easily be incorporated into the daily life of a child with cerebral palsy (solution designs do not necessarily have to be a product)
6.1.2 Detailed Objectives

Table 1. DfX’s to be considered, ranked in order of their relative importance (See Appendix B). For justification of the DfX, see the following page. (Blue: first high order objective, Orange: second high order objective)

<table>
<thead>
<tr>
<th>DfX</th>
<th>Objective</th>
<th>Metric</th>
<th>Criteria</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>To allow use by children with different levels of CP</td>
<td>Highest level with which the design is compatible</td>
<td>Higher is better</td>
<td>Must be compatible with level I, II and III in GMFCS</td>
</tr>
<tr>
<td>Usability</td>
<td>1. Opportunity for being multisensory (ex. sound, textures, and/or visuals)</td>
<td>1. Number of senses needed to manipulate the toy</td>
<td>1. More is better</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>2. Allow for imaginative play</td>
<td>2. Number of ways child with CP can interact with the design</td>
<td>2. More is better</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Minimize time needed to fully engage with the design</td>
<td>3. Time in seconds</td>
<td>3. Less is better</td>
<td></td>
</tr>
<tr>
<td>Affordability</td>
<td>Be affordable and financially viable for the average family that has a child with cerebral palsy</td>
<td>Canadian dollars (CAD)</td>
<td>Less is better</td>
<td>Should not exceed $62</td>
</tr>
<tr>
<td>Participation</td>
<td>1. To maximize engagement by the child</td>
<td>1. Time child remains engaged in the design</td>
<td>1. More is better</td>
<td>1. N/A</td>
</tr>
<tr>
<td></td>
<td>2. To maximize social interaction</td>
<td>2. Number of children who can play</td>
<td>2. More is better</td>
<td>2. Must have multiplayer options</td>
</tr>
<tr>
<td>Safety</td>
<td>Does not endanger the user as well as his/her surroundings</td>
<td>1. Number of injuries or fatalities associated with the use of the design</td>
<td>1. Less is better</td>
<td>1. N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Damage cost in CAD ($)</td>
<td>2. Less is better</td>
<td>2. N/A</td>
</tr>
<tr>
<td>Hygiene</td>
<td>To have the ability for the design to be cleaned or remain clean</td>
<td>Pass/Fail</td>
<td>N/A</td>
<td>Must be compatible with household cleaning products</td>
</tr>
</tbody>
</table>
7. Justification of DfX’s

Accessibility: This allows children with different levels of cerebral palsy to utilize the design (Compatible with GMFCS level III means the design is compatible with GMFCS levels I, II and III) [5].

Usability: The child is expected to learn how to utilize the design for future play without becoming distracted or frustrated. The success of this metric can be based upon whether the child remembers how to engage with the design in successive play sessions, or whether they choose to play with the design. More sensory stimulation aspects in the design are preferred because it contributes towards brain development in children, opening up neural pathways for other types of learning, such as social interaction. This enables children to learn to problem solve, collaborate, and share with one another [21].

Affordability: According to TheStreet, an American finance and business website, the average cost of the top 15 most popular toys in Toys R’ Us was $62 [22]. It was decided that the design should be cheaper than or equal to $62.

Participation: Since one of the main objectives of this report is to increase social interaction, design for participation is crucial. Maximizing both engagement to the design and social interactions involved with the design fulfills the first higher level objective (See Section 3.2).

Safety: An activity design must not endanger the well-being of any participants. Any product design must conform to Health Canada’s Safety Requirements for Toys and Related Products. For products, this includes considerations about choice of material, and several safety hazards [23].

Note: Because of the age range and the special needs of the children, supervision is always necessary to ensure a safe environment. It is assumed that all children will be under adult supervision while playing with the design.

Hygiene: Because the design is intended for children’s use, the need for hygiene is high. Without appropriate hygiene, children could become ill through the use of the design. We do not want the families of the children with cerebral palsy to buy special cleaning products to maintain the hygiene of the design. Thus, if the design needs to be sanitized, it has to be cleanable by household products such as ammonia cleaner and detergent [24].

8. Reference designs

Five reference designs developed for children with special needs are discussed below. The following describes how they work and how these reference designs fail to meet some of the requirements outlined in this RFP.
8.1 Textured Carousel Busy Box

Figure 2. A child playing with the Textured Carousel Busy Box [25]

The Busy Box [25], developed by Enabling Devices, has 6 plates with different colours and textures. Touching different plates results in different sounds produced by this toy and some pads cause the balls in the ball popper to move, creating diverse sensory stimulations in the child.

**Advantages:**
- helps the child to improve their visual, auditory, tactile and motor capabilities using colour, texture and movements (design for usability)
- can be rotated, allowing the child easy access to all the sides of the device if their level of CP does not allow for easy movement (design for accessibility)
- since there are 6 pads, multiple people can play with it simultaneously (design for participation)

**Disadvantages:**
- costs $247.95 (> $62; design for affordability)

8.2 In the Loop

Figure 3. A child with cerebral palsy playing with In the Loop

“In the Loop” consists of a track in which a ball is rolled. This increases dexterity and concentration as the tracks have to be opened and closed to control the motion of the ball.

**Advantages**
- Different difficulty levels and several weights for balls (design for accessibility)
- $23.85 (design for affordability)

**Disadvantages**
- Limited potential for multiplayer options (design for participation)
- Does not encourage imaginative play (only one way to interact with the design by opening/closing the track-design for usability)

8.3 Linelite Shower

Figure 4. Linelite Shower hung from the ceiling [26]
Developed by Flaghouse, Linelite shower consists of multi-coloured strands that glow under UV light and bells that ring when the strands move [26].

Advantages
- Heightens a child's senses by providing visual, auditory, and tactile stimulation (design for usability)

Disadvantages
- the strands pose a strangulation threat to a special needs child (design for safety)
- costs $298.75 (> $62; design for affordability)
- cannot be used by all children with CP because of its orientation (design for adaptability)

8.4 Modified Sports
Figure 5. A modified bicycle (left) and a modified sled (right) for rent in the Holland Bloorview sports equipment rental program. These two images were taken by a member of the RFP team while on a visit to Holland Bloorview Hospital.

Some adaptive equipment that help children with cerebral palsy engage in different types of sports are available, such as modified bicycles, sleds, and swings, and floatation devices for swimming, specially made to keep the child’s head above water at all times.

Advantages:
- the children are able to socially interact and actively participate within the sport (design for participation)
- the seats have straps so that the children are secured in place during play (design for safety)
- the equipment can be cleaned with common household products (design for hygiene)

Disadvantages:
- borrowed for free from the Holland Bloorview Hospital rental program for 2 weeks but afterwards, the renter must either pay a predetermined rental fee or buy the equipment (> $62; design for affordability). When looking at Zach’s List, an online classifieds site for pediatric equipment, a used tricycle designed for a child with CP cost $500 [27].

Note: The kicksled is an existing invention created by the Swedes [28]. Besides its advantages as sports equipment that children with CP are able to use safely, it is an example of how a pre-existing design can be adapted for different consumers. Additions to kicksleds such as an easily mounted child loop (which keeps children strapped safely to the sled) and a hammock (which can provide leg support to children afflicted in their lower body) are sold [29]. For a child with CP, these additions could mean the difference between not being able to participate in this sport to having a safe and comfortable time playing with their friends and family.
8.5 Virtual Music Instrument

*Figure 6. The Virtual Music Instrument in use by children* [30]

Developed by Professor Tom Chau at Holland Bloorview Kids Rehabilitation Hospital, the Virtual Music Instrument is an interface that uses motion detection to play music in response to a child’s gestures [31].

**Advantages:**
- highly accurate motion sensing programming (design for usability)
- can use any part of the body to facilitate musical responses (design for accessibility)
- stimulates visual, kinesthetic, and auditory senses (design for usability)

**Disadvantages:**
- requires a Windows-based computer as well as a webcam in order to function (design for affordability; design for usability)
- only one person can use the design (design for participation)
- costs about $500 to purchase the software alone (design for affordability) (See Appendix A.9)

There are many other research projects by Holland Bloorview Rehabilitation Hospital that try to improve the child’s development through sensory stimulation like switch accessible video games and Kinect Paint (See Appendix A.9) and other projects that focus on social interaction like an exergame (See Appendix A.7). However, all of these designs are more expensive than the ones mentioned above and failed to meet the requirements of the report.

9. Concluding Remarks

This request for proposal outlines the problem of inadequate low cost entertainment options for children with cerebral palsy. Due to the increased health expenses of families of children with CP, a focus of this RFP is to develop an inexpensive design. Since sensory stimulation and social interaction are key factors in the development of a child with CP, a usable design that enhances participation for children with level III or higher cerebral palsy in the GMFCS scale is required. Designs that will work for higher levels of CP are preferred since an accessible universal design will decrease or eliminate the need for adaptations of the design in the future. Safety and hygiene play key roles when determining an entertainment option because it is required to promote the well-being of children, especially children with disabilities. The reference designs critiqued do not fulfill all the requirements satisfactorily, which makes it difficult for families to provide their child with fun and low cost entertainment options. Stakeholder interaction has made it evident that any design should satisfy the requirements outlined in this report in order to be successful.
Appendices

Appendix A (Stakeholder Interactions)

Appendix A.1 (Megan Stuart)

On January 30th, our team met with Megan Stuart, Program Assistant of Educational & Recreational Services for the Ontario Federation for Cerebral Palsy (OFCP). We asked her questions regarding cerebral palsy. Her responses are summarized below.

Cerebral palsy (CP) is the most common disability in children, and the rates haven’t changed much. It is a condition that is non-progressive; although that does not mean it is unchanging. Currently, there is no cure for CP; however, the objective is not to cure this condition. Adaptability is favoured as the solution to the issues regarding CP, meaning that our goods and services should be able to accommodate people with the condition. One big improvement that Megan would like to see involves social issues surrounding CP, such as improving accessibility to social places like clubs and bars. Another thing that she emphasized was that every person with CP is unique, and therefore, they have their own specific needs and limitations. CP does not necessarily mean diminished cognitive ability. Additionally, specialized aid devices are relatively easy for children to obtain, while it is more challenging for adults. Near the end of our conversation, Megan introduced the problem regarding toys for children with CP. She stated that although there are some toys in the market specifically made for children with special needs, the prices for these toys are too high.

Appendix A.2 (Ben Scholes)

On February 7th, we interviewed Ben Scholes, Camp Coordinator at Variety Village. This facility provides fitness and sports-related activities to people of all ages and abilities, including children with cerebral palsy.

Our discussion was based largely on the fitness activities that Variety Village provides for motor-impaired children. We also discussed current and innovative products which help motor-impaired children partake in activities such as swimming and soccer. We conversed over the evolution of adaptive technology for the motor impaired such as stand-up wheelchairs and even equipment which allows the afflicted users to go hunting. After having been asked which activity the children most enjoy, Ben replied that swimming engaged and excited the children more than most other activities. His advice was to improve upon the involvement of mobility-impaired children in physical activities.

Appendix A.3 (Jennifer)

On February 7th, our team visited SickKids Foundation and talked to the Family Centre Resource librarian, Jennifer. Our initial purpose was to speak with children with cerebral palsy, but due to legal restrictions and the hospital’s policy on speaking with patients, we were unable to accomplish this task. Throughout this conversation, we learned about innovations such as Screenplay and the types of treatment that SickKids offers to aid children with cerebral palsy. She mentioned that play is used as a form of rehabilitation in children with CP to improve their development.
Appendix A.4 (*Mikey)

On February 11th, we gathered information from a 6-year-old child with cerebral palsy. The following are some responses from the child about his preferences for entertainment activities:

He liked large-piece puzzles, video games like Wii Sports, Playdoh, and reading books with pictures. He would rather play with friends than play by himself. Playing outside is fun only if there is snow; otherwise, he would rather play inside. He also stated that swimming is fun, and is one of his most favoured activities.

(*this name has been changed in order to protect the privacy of the individual.)

Appendix A.5 (Edin, Anna and Jacky)

On February 12th, we visited Health in Motion Rehabilitation Centre, a therapy centre that focuses on building independence in children with special needs, especially cerebral palsy. We observed the children at play at the rehab clinic and talked to three representatives of the clinic.

The children mostly use exercise balls to improve motor abilities and muscle function. The balls have different textures that can help the child with tactile recognition and sensory stimulation. They prefer natural, occupational therapy over machine-based therapy because it promotes independence and self-reliance. The representatives mentioned that boys prefer to do activities which involve hand-eye coordination (i.e. catching and throwing a ball), while the girls prefer movement activities such as crawling.

Appendix A.6 (Vicki Komisar)

On February 14th, we visited Toronto Rehab to speak with Vicki Komisar, a PhD student working in the biomedical industry. She mentioned that cleanability was a necessity for pediatric products. As well, she emphasized that each child is unique and that it would be very challenging to create a universal design. To overcome this, she suggested that modularity become one of our key criteria so that the design itself could be modified to suit a wider range of individuals. As well, she described the Virtual Musical Instrument, created by Prof. Tom Chau, and how it stimulates the senses of children with limited movement. She also mentioned that during game development, one main concern would be utilizing the concept of “easy-to-learn, hard-to-master.” By making a game that has a simple learning process yet is challenging to perfect, the child can maintain interest for an extended period of time.

Appendix A.7 (Darcy Fehling and her secretary, Lauren Switzer)

On February 14th, we visited Holland Bloorview Hospital to speak with Dr. Darcy Fehling, a developmental pediatrician who creates interactive video games, and her secretary Lauren Switzer. We learned that due to the lack of exercise that children with cerebral palsy engage in during childhood, they often transition from using a walker to having to travel in a wheelchair. She stressed the importance of exercise in children with cerebral palsy. As well, she mentioned that the new racing exergame (a video game that encourages exercise) she was developing required equipment which would cost a family from $1000-$2000. Lauren explained that in an effort to cut costs, the research and development team will look into making the exergame work with existing technology that the families already possessed, such as currently-owned recumbent bicycles.
Appendix A.8 (Bloorview School Authority)

Note: Names of students have been change to protect their privacy

On February 18th, 2014, we met with Pamela Speed, the Program Coordinator for the Bloorview School Authority, who offered to take us on a tour of the school. Our first stop was Paul’s classroom where children were sitting at tables playing with computer games. They were using assistive technology such as modified keyboards that had large buttons so the child with limited fine motor function could press each one easily. Paul mentioned that he would love to see some sort of device which would allow the children to perform functions that they would need in order to participate fully in sports, such as something to help wheelchair bound children kick or throw a ball. Paul had a large sandbox set up in the classroom that he said was used for sensory play as well as a way to learn about archaeology. We noted that alphabet and math posters were placed lower than usual along the wall and there were many carpets covering the floor. Hence, wheelchair-bound children can comfortably lie on the floor.

Next, we met with the occupational therapist, Betty. Betty described each child to us using the GMFCS levels, indicating that this classification system was the commonly used in the profession. She asserted that the children loved things that children without CP do, such as cars and dolls. She especially emphasized frequently that most of the “boys love cars”. She showed us Davey, who was using a switch to do his spelling schoolwork. The switch was a sensor strapped around his neck and against his throat. Every time a letter was highlighted on the screen, he would make a humming noise in order to select that letter to add to the sentence. The switch, which was connected to the computer, would transmit that hum into the equivalent of a mouse click. We were told that while Davey was not capable of participating even with modified equipment in sports, he loved to read. The other children in the room had more motor function and had just come in from an excursion outside in the snow. A girl, Julie, told us that she loves dolls, playing dress up, and throwing snowballs. The other boys in the room also affirmed that they liked playing in the snow, especially lying down to make snow angels. Betty also told us that the children would each have a weekly session at the Holland Bloorview swimming pool, and that most children like playing in the water because it is easier for them to move around.

Our following destination was the gym, where we met with the gym teacher, who has over 20 years of experience. Children played with assistants on modified skateboards with large platforms and four wheels so that the children could safely lay down on them and push using their legs. As well, a modified bowling alley was set up so that a child would only have to lift the foam ball up to a ramp, whereby the ball would roll along and knock down pins. The gym teacher gave us a book with pictures of all the gym equipment she used. These mostly included foam balls, discs, and foam noodles. She mentioned that the children loved to participate in gym and that social interaction was definitely encouraged by the staff. A modified game of tag included children in their wheelchairs with foam noodles attached on either end. If you were tagged with the noodle, you would become “it”. The noodles allowed for a wider reach and made up for the fact that the children could not move as quickly in their wheelchairs.

We then left for the complex care unit at the school, which included many children (not just those with CP). We saw children making arts and crafts, using modified tools such as scissors with a better grip and a stabilizing device that allowed them to cut a straight line. Other children did math online and played with balls. The supervisor of the unit told us that cleanability is a necessity because the toys had to be
cleaned after each use. Plastic toys were especially preferred because they could just be wiped down with a cloth and soap. However, plush toys such as teddy bears could only be given to children who weren’t sick or drooling.

When we returned to Pamela’s office, she told us that many of the children use assistive technology for play or schoolwork but perhaps would be more engaged in activities if they weren’t using technology all the time.

Appendix A.9 (Fanny Hotze)

After our initial visit, we were invited back to Holland Bloorview to tour the PRISM (Paediatric Rehabilitation Intelligent Systems Multidisciplinary) lab with technology specialist Fanny Hotze. During this tour, she demonstrated some of the games and technological advancements developed at Holland Bloorview. We were given the opportunity to test each of the games. A large portion of the games were computer-related, with input signals through throat vibrations, eyebrow movement, and head movement. We also tested the Virtual Music Instrument (See Section 8.5) and a new Kinect Paint game that involved virtual painting on a monitor through the use of limb movement and advanced motion detectors. In our discussion with Fanny, the importance of switch toys was evident. Switch toys use one or more basic input signals to accomplish a task for the user, such as moving a character in a video game or causing a toy to emit sound. Fanny described how beneficial it was for the child to both experience an enjoyable play session while being motivated to use parts of their bodies with limited mobility. All the toys she mentioned were expensive (ranging from $500-$2000) and some of them were only for research purposes and not for sale. She mentioned that the biggest challenge in designing for children with CP is that every child is different and so an accessible design is needed.
Appendix B (Pairwise Comparison Matrix of DfX’s)

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Using holistic judgement and numerous interaction with occupational therapists, children with CP, representatives from OFCP, and other stakeholders, we have ranked the DfX’s according to their relative importance. The ranking of the DfX’s in the pairwise comparison matrix are as follows: Accessibility, Usability, Affordability, Participation, Safety and Hygiene.
Bibliography


