Understanding Family Needs: Informing the Design of Social Robots for Children with Disabilities to Support Play

By

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Abstract

Children with disabilities often have fewer opportunities and motivation for play, impacting their cognitive and social development. This has resulted in the development of therapies to facilitate or encourage children's play and thus support their development. We posit social robots have the potential to support children with disabilities to play, as research has demonstrated how social robots can motivate children, increase their engagement in a task, and help facilitate social interactions. However, a challenge with both social robots and technological interventions is that families and children often struggle to adopt them into regular use, abandoning them after only a short time. As such, our approach is to begin our investigation into the requirements needed for social robots to support play by examining the needs, concerns, and barriers of the family unit as a whole – guardians, siblings, and children living with disabilities – to serve as a cornerstone for developing potential social robot interventions to support play.

We conducted a study with eight family units to learn their thoughts about the barriers and requirements for a successful social robot intervention. Combining the insights gathered following our qualitative analysis with our knowledge from our literature review, we outlined recommendations and considerations needed to direct future research on how to

leverage a social robot for facilitating play. This thesis gives us starting insight into understanding important factors to consider for social robots to supporting children with disabilities.

Dedication

To my mom,

for supporting me throughout my life and degree.

I will continue to make you proud.

Acknowledgments

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Publications

Some ideas and figures in this dissertation have appeared previously in the following publications by the author.

Raquel Thiessen. 2023. Social Robots to Encourage Play for Children with Physical Disabilities: Learning from Family Units. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction, 784–786. (Poster Presentation)

Raquel Thiessen, Minoo Dabiri, Denise Y Geiskkovitch, Jacquie Ripat, and James Everett Young. 2023. Social Robots to Encourage Play for Children with Disabilities: Learning Perceived Requirements and Barriers from Family Units. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction, 625–628.

Chapter 1

Introduction

For children, play is a crucial aspect of their development and a fundamental human right [13], [14]: through play, children develop their physical, emotional, social, language, cognitive abilities, and creativity [15], [16]. However, the time for children to play continues to decrease [17], especially for children with disabilities who often face added barriers and challenges to play. For example, they may need to dedicate time to therapies, experience limitations due to physical or cognitive impairment, or deal with a range of social and environmental barriers [18], [19], and therefore may experience isolation from their peers [20]. Insufficient play opportunities can also lead to children erroneously believing they are incapable of performing tasks despite having the ability to do so (i.e., “learned helplessness,” [21]). Several interventions have been defined to enhance children’s play participation like designing play environments [22], working on children’s play skills [23], or using technology [24]. Among interventions to support play and alleviate barriers, there are early indications that social robots can motivate and encourage children to play and facilitate social interactions necessary for social play [25]–[27]. However, social and domestic robots, in general, have faced adoption challenges with integrating into sustained use due to issues designing for long-term engagement, not meeting users' expectations, and not meeting families' social and pragmatic needs and constraints [28], [29]. In this work, we took a user-centric approach to learn of the desires, concerns, and barriers of children with disabilities and their families for a social robot for play to improve the chances of adoption.

Social robots use human or animal-like social behaviors [30] and a physical presence [31] to create a highly engaging and unique interaction experience [32]. Use of social robots has been explored to support children with neurodevelopmental disorders [33], [34], for example, to successfully motivate children in their therapies [35] and help foster interactions with peers [36]. However, widespread impact will require acceptance from the family and integration into an individual and their family's home and routines [37]. Some research has demonstrated challenges with the creation of successful robotic interventions to support children with disabilities (e.g., [35], [38]), for example, the robot not being well adapted for their specific needs [35], [39]. We pursue this problem by engaging with children and their families to reflect on adopting a social robot.

We iteratively worked through designing a study that would allow us to engage with families with children with disabilities while considering our time, space, and recruitment constraints. This dissertation will discuss the process of designing the study, figuring out the specific co-design activities, and the design process of creating the 3D printed toolkit used for the creation activity. We will also outline the challenges we had throughout the process and how we addressed some of these challenges.

We recruited and engaged with children (aged 3.5-11) living with disabilities, and their immediate families, to obtain their opinions on potential social robot interventions. Our study did not specifically target a specific category or type of disability. We chose to do this both to be inclusive and to help with the recruitment challenges we faced with a limited number of children fitting our criteria. We did not require confirmation or verification of the disability they had. Instead, we relied on the judgment of the family to determine whether their child fell within the general category of living with a disability. We designed and conducted the study to engage the family units in reflection exercises, drawing from co-design techniques (*Figure 1.1*), to understand their perspectives on potential benefits, pinch points, and the practical and social landscape of adopting a social robot for children with disabilities.

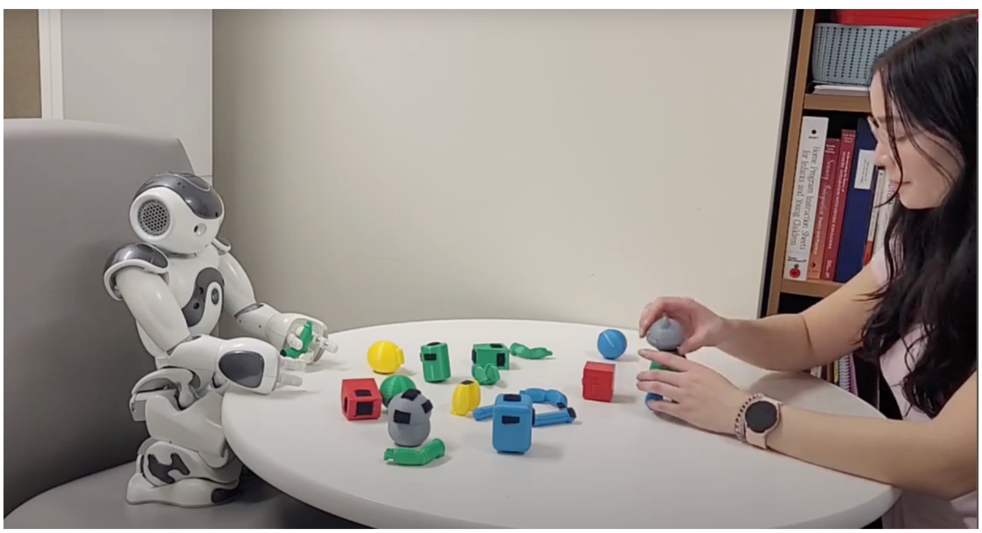


Figure 1.1 Study Example of the researcher going through the creation activity with the robot posing as a child

This dissertation aims to investigate the following research questions:

1) What are the concerns of children with disabilities and their families regarding social robots and perceived barriers to adopting a social robot for play?

2) What are the desires of families with children with disabilities and perceived opportunities for a social robot for play?

3) What are the specific play use cases that children with disabilities and their families envision for a social robot?

4) What ideas do children with disabilities and their families have about their social dynamic with a social robot and the role it would play?

In this dissertation we present a study design, implementation, and deployment of our study. We present the results from conducting this study with family units where we learned the needs and barriers they believe would exist with a social robot intervention. Overall, participants were receptive and intrigued by the idea of a social robot in their homes but had concerns regarding the safety of the robot and the safety of their child with the robot. From this, we developed preliminary recommendations and considerations to improve future robot prototypes for long-term domestic robots to support play for children with disabilities.

1.1 Play

Play, as described in a number of previous studies and research papers, is universally recognized as the primary occupation of all children [13], [14]. It is not just an enjoyable or fun activity but is also considered a fundamental human right, emphasizing its significance in all children's lives. Although the definition of play has evolved throughout time and across research fields, it is commonly understood as a voluntary and intrinsically motivated activity [40]. While play activities themselves may not have a specific or immediately practical purpose, the true importance of play lies in the significant impact it has on a child's overall development.

Play is widely acknowledged for its role in shaping a child's physical, social, emotional, and communication skills, as well as fostering their creativity and problem-solving abilities [15], [16]. Through play, children engage in various experiences that allow them to simulate real-life conflicts, work out solutions, and express their frustrations in a safe and supportive environment [41]. By engaging in imaginative and exploratory play, children develop their cognitive abilities, enhance their social interactions, and strengthen their emotional regulation skills. Moreover, play provides a platform for children to practice and refine their communication skills, both verbal and non-verbal, as they interact with peers and engage in collaborative play [42]. Overall, play nurtures the development of vital life skills and empowers children to navigate and understand the world around them.

In spite of the evidence supporting the role of play in children's development, there has been a notable decline in play [17]. This is particularly relevant for children living with disabilities, who may face additional challenges to play beyond the cognitive or physical consequences of their disability [18]–[21]. Factors such as social isolation, limited access to inclusive play environments, or reduced sense of self efficacy can further restrict or diminish play opportunities for these children [18]–[21]. Play deprivation can lead to deficiencies in emotional regulation, strength, communication, problem-solving abilities, and social skills [43], [44]. To address this issue, we propose the use of social robots as a valuable tool to facilitate and encourage play in children with disabilities.

1.2 Potential of Social Robots

Figure 1.2. Paro Robot as an example of a social robot, taken from [1]

In recent years, there has been a growing body of research dedicated to exploring the potential of social robots in supporting individuals in their daily lives. Social robots are designed to interact with people using social norms and standards, often taking on humanoid or animalistic appearances, such as a dog like Sony Aibo [8] or seal like Paro [1] (*Figure 1.2*). Their social capabilities have allowed these robots to be utilized across various age groups, including children, adults, and older adults.

Social robots have also been employed in a diverse range of applications, including mental health [45], education [46], rehabilitation [47], [48], social therapies [49], [50], and play [35]. The existing research on children with disabilities has predominantly centered around therapeutic applications and robots that offer physical assistance during play. Specifically, studies involving social robots for children with disabilities have primarily focused on those living with neurodevelopmental disorders and supporting their corresponding therapies. Additionally, research on children with physical disabilities has often revolved around non-social robots that provide physical adaptations to facilitate their participation in play activities [3], [51]. Our project takes a different approach, aiming to explore the potential of social robots to facilitate play experiences for children with disabilities more broadly. We aim is to widen the scope and examine how social robots can facilitate and support play experiences for children with various types of disabilities.

We recognize that social and domestic robots have faced challenges in achieving sustained adoption due to issues related to long-term engagement, not meeting user expectations, inability to fulfill the social and pragmatic needs of families, and not addressing practical constraints [52]. Some previous research has investigated these adoption issues, and we wanted to build on this work, trying to understand where the similarities of adoption challenges might lie for families with a child with a disability. Our research explores this through a co-design-inspired approach, actively involving families to gain a deeper understanding of their needs and concerns. By examining the intersection of what is technically feasible for social robots and the perspectives of children with disabilities and their families, our project aims to contribute to the future design and development of social robots that can support these children effectively.

1.3 Methodology

In our research, we developed an approach to gain a deeper understanding of the factors to consider when designing social robots for children with disabilities. Our primary objective was to engage with family units and gather their perspectives on the potential use of social robots, as well as their concerns about having such robots in their homes. We also wanted to ensure that we grounded the participants in what is technically feasible, showing them a bit about what real robots look like. Given these goals, we developed a study with a robot demonstration and a follow-up co-design activity.

The initial phase of our study involved showcasing a demonstration of four different robots to the participants (guardian and children). This demonstration helped familiarize the family units with social robots' current capabilities and appearances. With this demonstration, we aimed to provide a foundation of existing technological capabilities for the follow-up co-design activity and discussions. We included a reflection exercise after the demo to initiate the brainstorming process and establish rapport between the researchers and the family unit.

The core of our study revolved around the co-design activity, which allowed the children and their family to actively engage and express their opinions, needs, and concerns. We provided the children with a choice of a 3D printed toolkit or drawing materials, enabling them to create their own robot prototypes. The prototypes served as a tool that facilitated discussions about social robots and their potential for supporting play. Through a series of semi-structured interview questions (*Appendix F*), we encouraged the children and their family to share their thoughts, concerns, and any challenges they expected or perceived in integrating social robots into their daily lives.

To begin running our study, we needed to connect with a center that would allow us to gain access and work with our target population. Fortunately, we were able to leverage existing connections of our collaborator, Dr. Jacquie Ripat from the Occupational Therapy Department at the University of Manitoba, who had prior connections with Specialized Services for Children & Youth (SSCY) center and had experience working with the center, which proved invaluable in facilitating our connection to the center's activities and the larger community. We tried a few different setups for recruitment, such as walking around the building, walking up to people, or sitting in areas that more likely had our participant population. Ultimately, we decided on a booth in the front entrance area of SSCY, where we showed two of our robots.

Following the completion of our study, we employed directed content analysis to analyze the audio recorded interview data and identify emerging themes. Through our qualitative analysis, we found meaningful insights into the practical and social aspects social robots should follow to support children with disabilities to play. Based on the identified themes, we developed recommendations to guide future research developing social robots tailored to the unique needs of children with disabilities.

We aimed to bridge the gap between current literature on designing social robots for play and the lived experiences and needs of children with disabilities and their families. Our approach provided a starting point for understanding the specific requirements and challenges associated with incorporating social robots into the lives of children with disabilities. Ultimately, our findings contribute to the research of designing social robots that can encourage and enhance the play experiences of children with disabilities.

1.4 Results

Based on our findings from our eight family units, we formulated several preliminary recommendations regarding the concerns and considerations for designing social robots to support children with disabilities in play.

During our research, we explored the concerns and barriers of families regarding a social robot to support a child with disabilities with play. One concern raised by both guardians and some children was the safety of the robot. Guardians were especially worried because of their perception of the high cost of a robot, that it would be mistreated or broken by their children. Additionally, guardians mentioned safety considerations for their child, although discussions on this topic were relatively limited compared to those regarding robot safety.

When exploring the role they wanted for the robot, it became evident that families expressed a desire for a companion robot that actively engaged in their child's activities and interests. For families that talked about a pet companion robot, guardians discussed how a social robot would provide their child with an opportunity to learn about taking care of a pet, the responsibilities, and gain an experience they would not otherwise be able to have. Families also talked about the potential of their companion social robots in supporting various therapies, including physical and speech therapies.

Our study's outcomes indicate that families are receptive to the potential of integrating social robots into their child's playtime, as they perceive these robots as capable of motivating and supporting their children. Our study provides nuance and insight into their desires for such a robot. We define general recommendations that can provide a starting place for future social robot prototypes to support play for children with disabilities.

1.5 Contributions

The impact of our work can be characterized by the following contributions.

- We actively involved the community at SSCY, providing them with opportunities to interact with real robots and share their perspectives on various aspects, including their needs, desires, concerns, and more.
- Our study stands out as one of the few research studies that has sought to engage family units with children with disabilities directly through co-design activities, enabling us to gain insights into the unique requirements and design specifications necessary for social robots to support play for children with disabilities.

- Our research expands upon previous research with children with diverse abilities. Using our data, we developed initial high-level guidelines and recommendations for researchers involved in the design of robotic interventions for play.

We acknowledge that this research represents an early stage in addressing the greater issue of adoption and design challenges, but our work lays a starting foundation for future endeavors in leveraging social robots to facilitate play.

1.6 Dissertation Overview

Our work builds on existing research on social robots for supporting children in play, aiming to highlight the broader role of social robots in supporting children with disabilities play for play's sake. In this dissertation, we describe our entire process. Starting in Chapter 2, we delve into the concept of play, exploring its significance, impact, and the current landscape of play interventions for children with disabilities. In Chapter 3, we introduce the interdisciplinary field of human-robot interaction (HRI) and summarize the existing research utilizing social robots with children in different applications. This review serves as a foundation for our study, highlighting the gaps and opportunities for further exploration. Chapter 4 discusses the challenges we encountered and overcame during the design of our research study. We outlined the complexities and considerations we had to take when working with children with disabilities, ensuring that our study design was inclusive and ethically sound. Next, we detail our study methodology, outlining how we engaged participants and gathered our data for our research questions in Chapter 5. We then present a comprehensive summary of our research findings and offer practical recommendations in Chapter 6. These recommendations serve as a guiding framework for designers and developers of social robots, enabling them to effectively adapt their creations to meet the specific needs of the children they aim to support in play. Finally, in our concluding chapter, we reflect on the contributions of our research, its implications for future studies, and the potential for future work in using social robots to encourage and support play experiences for children with disabilities.

Chapter 2

Background: Play

In this chapter, we provide an overview of play and its profound impact on a child's growth, learning, and overall well-being. We begin with a broad summary of play, exploring its various forms and discussing its essential role in shaping a child's development. Recognizing the significance of play in the lives of children, we shift our focus to play interventions for children with disabilities. These interventions help facilitate and enhance their play experiences, fostering their engagement, social interaction, and overall development. Play is not only the primary motivation of our work, but understanding play and play interventions allowed us to envision how a social robot could contribute to supporting children with disabilities in play. By delving into play, we draw inspiration and insights that inform our study design and analysis.

2.1 What is Play?

For children, play is a fundamental human right [13], [14]. Definitions of what play entails have varied over the years [53], but we focus on play as an enjoyable, voluntary, intrinsically motivated activity [40]. Play is a human right because it allows children to use their creativity while developing their imagination and physical, cognitive, and emotional abilities [15], [16]. Play also allows children with limited verbal abilities to express their views, experiences, and even frustrations, allowing their caregivers or therapists to understand their perspectives. Despite the benefits, time for play has decreased for some children, especially children with disabilities [17]. Children with disabilities can have fewer play opportunities because of their need to devote time to other therapies and the impact of their physical, social, and environmental barriers [18]. These barriers can lead to delays in a child's development of skills, such as their cognitive, social, and motor skills [18].

Play is a complex concept with various components depending on the context and the child's developmental stage. The stages of play proposed by Piaget [54] outline children's progression of play driven by their cognitive development. The first stage is sensory-motor play, which involves activities that stimulate the senses and motor skills. These activities can range from simple exercises like tummy time for infants to more complex actions such as throwing a frisbee. Sensory motor skills include sensory abilities like vision, hearing, and touch, as well as motor abilities like walking, talking, and running. The next stage is symbolic play, typically observed between the ages of 2 and 7. Symbolic play is a simple form of pretend play where children begin to symbolically represent knowledge, experiences, and objects. For example, a child using a banana as a phone would represent symbolic play. The final category is complex pretend play, which can incorporate symbolic play but is generally a more intricate form of pretend play. It often involves activities like role-playing, where children take on different roles and act out scenarios.

By learning about the impact and evolution of play and the challenges faced by children with disabilities, we can better understand the requirements for developing social robots that support and promote play.

2.2 Impact and Importance of Play

Play is a vital part of children's lives, as it contributes significantly to their overall well-being and development. Through play, children engage in activities that promote physical, cognitive, social, and emotional growth.

Physically, play encourages the development of children’s motor skills, coordination, and balance. It allows children to explore their surroundings, improve their strength and physical fitness [55]. Cognitively, play provides a way for children to learn and understand the world around them. It promotes problem-solving skills, creativity, critical thinking, and imagination [56]. Play allows children to experiment in a safe environment, make decisions, and engage in logical thinking, enhancing their cognitive abilities. Additionally, play promotes communication and language development as children engage in imaginative play scenarios alone or with other children [56]. Socially, play facilitates the development of necessary social skills. Children learn to interact, share, cooperate, and work collaboratively with their peers. During play, they may engage in activities such as role-playing, which helps them understand different perspectives, practice empathy, and develop relationships and friendships with others [55]. Play can also promote teamwork, leadership, and conflict resolution skills, preparing children for navigating social situations and conflicts throughout their lives [55]. Emotionally, play allows children to explore and express their feelings, experiences, and fears in a safe and supportive environment. Play can help with stress, anxiety, and emotional challenges, giving children the opportunity to develop resilience and help their overall emotional well-being [57].

Play has a significant influence and impact on the lives of all children. Therefore, promoting and creating opportunities for play in children's lives is crucial as it serves as the foundation for their development. Furthermore, play is a joyful and fun aspect of childhood that every child should have the opportunity to experience. Our research explores the requirements and potential of social robots to encourage children's play, not only for its developmental impacts but also play for play’s sake.

2.3 Play Environmental Factors and Interventions

Previous research has highlighted the significant role of environmental factors in shaping the play experiences of children with disabilities [58]. Specifically, the environment setup and nature of the activity were found to have an impact on the peers of children with disabilities perceptions of inclusion and fairness, as well as their decisions regarding whether they should include the children with disabilities [59]. Furthermore, the type of toys influences the facilitation of play for children. For instance, a study revealed that offering children a choice of toys and providing positive praise for playing with them increased their play with the toys [60]. Previous research has also highlighted the influence of using social toys, such as blocks and dolls, on promoting cooperative play among children with disabilities, emphasizing the role of these types of toys in fostering social interaction and collaboration [61]. The types of activities also influence the engagement of children with disabilities in the activity. The activity needed to be able to be adaptable for children with different abilities to participate and to promote all the children playing together [59].

Peer-based play interventions with children with disabilities are an effective method of for promoting play. One type of peer play intervention involves scheduled playdates. During scheduled playdates, children with disabilities engaged in various activities with their peers, providing them with more opportunities to learn and apply their social and communication skills in different environments and with different children [62]. Participating in playdates not only facilitates skill development, but also encourages relationship building, and friendship development, and overall contributes to developing socialization abilities of children with disabilities [62], [63]. Even if children with disabilities do not currently have all the necessary skills for interacting and playing independently with their peers, being in the presence of their peers is crucial for their play skill development [62], [64]. Another approach to peer-based play interventions involved leveraging the peers of children with disabilities to motivate the children and to facilitate inclusive play. In these interventions, peers initiated and encourage social interactions with children with disabilities. As a result, these interventions created more play opportunities and enhanced social interactions between children with disabilities and their peers [65]. By promoting these interactions, peer-implemented interventions can improve social play behaviors and developing social and communication skills in children with disabilities [66]. Similarly, a social robot could perhaps do these interventions as a facilitator and motivator for children's play. Integrating a social robot in such interventions can provide additional support and encouragement for children with disabilities to engage in play activities [67], [68].

Another type of play interventions utilizes adult facilitators. One example is a play intervention called modeling. Modeling has been an effective strategy for facilitating skill development in children [69]. Through imitation and modeling techniques, children are taught specific skills through observation and practice. Video modeling can encourage children to learn play skills through observational learning [70]. In this intervention, they showed a video showcasing various play activities or actions, and the children were encouraged to mimic the behaviors shown in the videos. This visual representation allowed children to observe the desired actions and engage actively in learning the skills. The video format allows for more control and consistency of the model, and these videos can be repeatedly shown to the child and used for multiple children [62]. Modeling can be in an in-person format through live modeling. Researchers have explored using live modeling combined with verbal descriptions, and found that children demonstrated the modeled play skills following the intervention [71]. By incorporating modeling interventions into the play and learning process, children gain more opportunities to play and acquire new skills, enhancing their overall development and growth.

In our research we consider factors and types of interventions that should be considered for having the robot help facilitate play.

2.4 Play as a Foundation for Social Robots

In this section, we went into the background of play, describing its significance and impact on the well-being of children. We then reviewed various play interventions, such as peer-implemented interventions, that have been implemented and leveraged in the past to support children with disabilities in their play. A comprehensive understanding of play, the evolution of play, and currently used play interventions, can help inform the potential for social robots in this area and allow us to consider how social robots could similarly be incorporated and utilized to support play. Throughout this dissertation, we explore the potential of social robots as a tool for supporting and encouraging children with disabilities to engage in meaningful play.

Chapter 3

Related Work

This chapter describes related work that provided a solid foundation and informed our study design and research methodology. By summarizing related work and known benefits of social robots in supporting children's play, we establish the significance of our study within the field of Human-Robot Interaction and justify our study design decisions. We provide a summary of the field of Human-Robot Interaction, emphasizing the significance of adopting an interdisciplinary approach to address the complex challenges in this field. Building upon this, we explain our decision to focus on social robot technology for supporting children, briefly describing their advantages over other forms of technology. We specifically narrow our focus to social robots designed for children with disabilities, recognizing the importance of addressing their unique needs and challenges. Lastly, we talk about previous studies that have used co-design techniques, showing the valuable contributions made by engaging children in the design process. Overall, this review of related work sets the stage for our research, positioning it within the broader context of social robots, play, and children with disabilities.

3.1 Human-Robot Interaction

Researchers in Human-Robot Interaction (HRI) investigate a variety of challenges regarding humans interacting with robotic technologies. The study of HRI investigates various aspects of the interaction between humans and robots, such as the technical, social, and ethical dimensions. The multidimensional complexities of the research in this field highlight the need for an interdisciplinary approach to understand and navigate these challenges.

From the technical perspective, researchers seek to develop robots that are safe, reliable, and capable of understanding human communication, expressions, and behaviors. These researchers work on exploring ways to create intuitive interfaces [72], enabling effective communication methods [73], and designing robot behaviors that are both practical and socially acceptable [74]. Through HRI the societal impact of robots and the factors influencing human acceptance, trust, and adoption [75]–[77] are also investigated. For example, researchers explore social and psychological implications of human-robot interactions, investigating how these interactions can affect human emotions and behaviors. Researchers also explore people's perceptions and concerns regarding privacy [78], ethics [79], and cultural sensitivity [80], seeking to develop guidelines and frameworks that ensure responsible and more successful robot design and deployment. Similarly, in this dissertation, we investigate various factors that could influence the success of the adoption of a social robot for play with children with disabilities to provide recommendations for future researchers.

3.2 Why Robots?

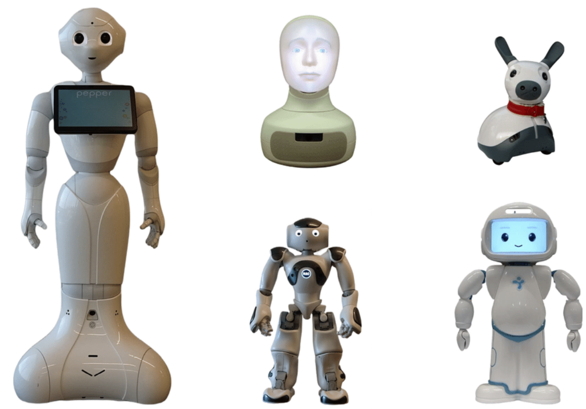


Figure 3.1. Examples of social robots, taken from [2]

Research has demonstrated humans subconsciously treat media as they would with a real-life person or situation, no matter how much they know or think about it [81]. Research suggests the level that you experience this will depend on factors such as age, gender, and culture, but in the end, it is a natural response for all of us. There have been multiple studies showing this is true for characteristics such as politeness [82], motion [83], emotion [84]–[86], and social roles [87]. This research further demonstrated that people naturally will interact with technology as they would with the real world in everyday life, which we can leverage in our designs for supportive social robots.

Various types of technological agents exist, including co-present robots, tele-present robots, and virtual agents. While these agents can serve similar purposes, co-present robots stand out due to their physical embodiment and presence with the user. A physical embodied robot has a physical instantiation, allowing the robot to utilize social cues and non-verbal communication such as gestures, facial expressions, and body language [88], [89]. Additionally, co-present robots can utilize haptics and proxemics for communication, which are not feasible in virtual environments. Moreover, co-present robots can interact with the physical environment, enhancing the interactive experience. Previous research has shown the differences between these types of agents, with co-present robots eliciting stronger emotional responses, enhancing enjoyment, and promoting engagement compared to tele-present robots, making interactions more compelling and meaningful from a human perspective [88], [90], [91].

While virtual agents and tele-present robots have advantages, such as flexibility, cost-effectiveness, and easy distribution, robots with a physical embodiment offer benefits that enhance user experience and effectiveness of their interventions. For these reasons, we chose to leverage social robots to support children with disabilities in play.

3.3 Social Robots

Social robots are robots designed to interact with people in a social matter, using social norms and standards [92] (*Figure 3.1*). These robots typically take a biomorphic or anthropomorphic form, with abilities such as perceiving and understanding human behavior and communicating with social behaviors such as facial expressions, eye contact, gestures, and speech [93]. Imitating the qualities of social beings, social robots focus on engaging in meaningful interactions with their users and supporting them in various ways.

One example of social robots supporting people is in healthcare centres. Social robots have shown promise in multiple areas supporting older adults [94], adults, and children, assisting with rehabilitation [38], promoting social interaction [33], and providing emotional support [49]. Through their physical presence, embodiment, and capabilities, social robots act as a tool to improve healthcare services and the overall quality of support for patients.

Another example of social robots supporting people in education. The incorporation of social robots in academic environments holds the potential to enhance the learning experience. These robots can engage children through dynamic and interactive activities, promoting children's participation and motivation in learning [95]. Furthermore, social robots can be used to facilitate social-emotional development by helping students develop social skills, empathy, and emotional regulation [96].

One of the key challenges in human-robot interaction is ensuring long-term engagement and sustained use of social robots. Researchers are exploring factors that influence long term engagement and ways to design social robots that maintain users' interest and adapt to evolving needs over extended periods [52], [97]. Long-term interaction involves creating robots that establish and maintain relationships with the users, learn from their preferences and behaviors, and evolve their behaviors to support the user. By focusing on long-term interaction, researchers aim to develop social robots that can seamlessly integrate into users' lives, providing continuous support, companionship, and assistance.

We contribute to previous research by looking at how social robots can support children with disabilities in play. To develop recommendations for designing social robots for children with disabilities, we worked with children and their families to understand their needs and identify any concerns they would have with a social robot in their home.

3.4 Social Robots for Play and Children with Disabilities

In the past, non-social robots were predominantly utilized as tools to facilitate play for children with physical disabilities. For example, Mahdi et al. [3] aimed to address the limited play opportunities for children with physical disabilities by designing a remote-controlled non-social robot (*Figure 3.2*). This robot allowed children with varying ranges of movement to engage in collaborative play with their peers, as it had adjustable levels of autonomy. The researchers found that this design helped mitigate the challenges caused by differences in mobility. Similarly, Lindsay and Lam [36], conducted a project where children transitioned from solitary play to parallel or cooperative play over time during an adaptive LEGO robotics program involving a non-social robot.

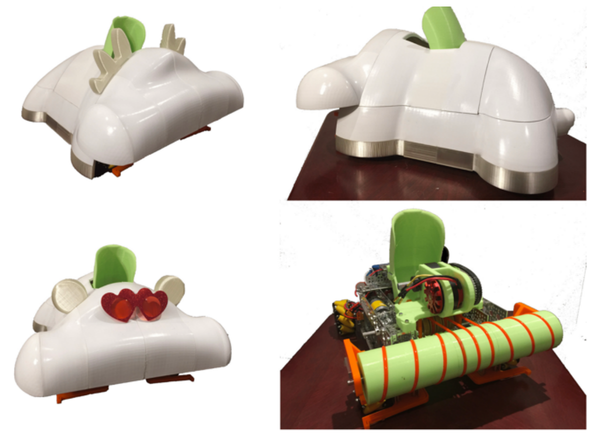


Figure 2.2. myJay robot designed by Mahdi et al., taken from [3]

These studies suggest that programs with robots like this could effectively facilitating collaborative play for children with physical disabilities. In the past, non-social robots were predominantly utilized as tools to facilitate play for children with physical disabilities. Our research delves into the novel use of social robots for children with diverse disabilities, including those with physical disabilities, which has been relatively unexplored until now.

Previous research has investigated the types of play children engage in when playing with a robot. In a study involving a child-operated robot, researchers discovered that the level and quantity of pretend play increased with age [98]. Younger children tended to engage in more functional play with the robot, while older children incorporated pretend play or role-playing elements more frequently. Young children struggled with incorporating the robot into their pretend play, indicating a need for further exploration and understanding of the factors that influence the type of play children can do with social robots.

Commonly, social robots have been used in research on children with neuro-developmental disorders. For example, the social robot KASPAR was utilized in a study with children on the autism spectrum, demonstrating improvements in their social behaviors during play [33]. Previous research demonstrated the value of collaboration between researchers, therapists,

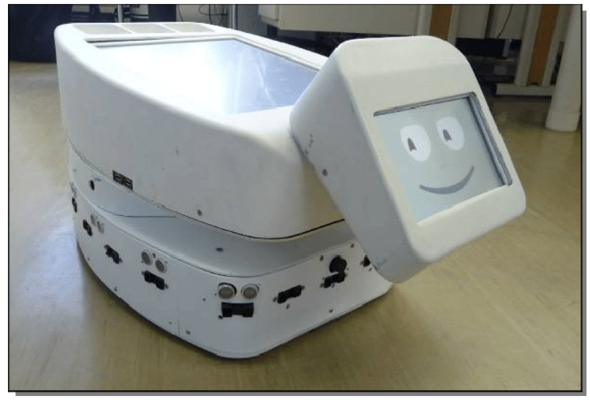


Figure 3.3. IROMEC Robot, taken from [4]

and professionals in the development of robots to support children with disabilities. For example, the Teo robot was designed in collaboration with therapy professionals to foster free play among children with neurodevelopmental disorders. [99]. The therapists involved in the study agreed that Teo elicited more social interaction and other encouraging behaviors. However, their results showed minimal evidence of these benefits as there was a small population size and numerous variations between participants. In the IROMEC [4], [38], [39], [100] project (*Figure 3.3*), researchers built a robot tailored for interactions with children with physical disabilities and those on the autism spectrum. Their requirement to meet the needs of both groups of children was a major limiting factor because of their conflicting needs. For both groups of children, the robot could not fulfill their needs and expectations. Our research will focus on bringing in insights from the families of these children to provide their perspectives and generate grounded recommendations on how to design such robots. These insights will allow researchers and professionals to understand the practical and social landscape the robot needs to be designed within.

The previously mentioned research projects had custom-built research robots, but there has also been some research testing commercially available devices. Researchers found that the ZORA robot [35], [101] elicited many positive, such as increased concentration and attention of the child with disabilities. However, there were many technical challenges with the robot, including the lack of scenarios and the professional's inability to customize the scenarios independently for their sessions. Our interpretation is that potentially their design did not sufficiently consider users' needs and social structures. Thus, in our work we tried to take a step back and work with children and their families to get a clearer sense of the user requirements for such a social robot. However, knowing what commercially available robots exist and their limitations can help ground our ideas with current technological feasibility.

3.5 Co-designing Robots with Children

Involving children in the design process is becoming increasingly prevalent in Human-Robot Interaction. The aim of these approaches is to obtain direct input and feedback from primary stakeholders regarding general needs, concerns, and innovations. Co-design techniques have been employed in previous studies to engage a wide range of aged children to design robots for creativity [102], mental health [45], and education [46]. The researchers in each case gathered data and conducted analysis to develop guidelines for designing robots tailored to their specific cases. This data was utilized in some instances to construct, test, and assess the subsequent robot prototype. Moreover, the children had the opportunity to engage in a valuable learning experience centered around robotics and user design.

Figure 3.4. Co-design activity performed with children, taken from [5]

Our methodology was inspired by a study where researchers worked with children and their parents to explore design requirements for a social robot to help a child with pain management [6] (*Figure 3.5*). Before their session, they introduced the children to a handful of robots and allowed them to spend time interacting with them. Similarly, we included a section in our study to help ground the stakeholders with what is currently technically feasible for a social robot. These methods show the efficacy of using this technique with children and outlined a potential structure of how we could run the session, the activities that worked best, and potential issues that might arise.

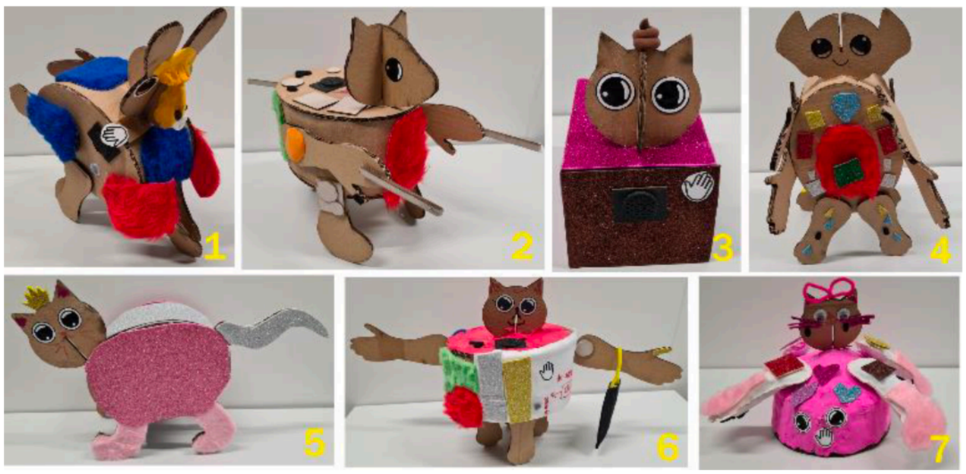


Figure 3.5. Resulting co-design prototypes from a study done with children, taken from [6]

3.6 Related Work Overview

In Human-Robot Interaction (HRI), researchers examine the technical, social, and ethical dimensions of humans interacting with robots. They work to develop physically safe and reliable robots that can understand human communication and behaviors. Researchers use these robots to explore societal impacts and factors influencing their integration, such as acceptance, trust, and adoption. Past research showing that people interact naturally with technology informs our focus on co-present robots, considering their physical embodiment that enables rich non-verbal communication and intuitive interactions. Social robots have been used in multiple applications showing their positive influence and support of children in many domains. In this dissertation, we specifically investigate the potential of social robots to support play among children with disabilities, aiming to provide recommendations for future research and contribute to developing inclusive technologies that enhance their well-being and play experiences.

Chapter 4

Study and Methodology Design Challenges

Work presented in this chapter has previously appeared in the following publications:

> Raquel Thiessen. 2023. Social Robots to Encourage Play for Children with Physical Disabilities: Learning from Family Units. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction, 784–786.

> Raquel Thiessen, Minoo Dabiri, Denise Y Geiskkovitch, Jacquie Ripat, and James Everett Young. 2023. Social Robots to Encourage Play for Children with Disabilities: Learning Perceived Requirements and Barriers from Family Units. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction, 625–628.

In this chapter, we review the challenges we faced when designing a study to explore the requirements for a social robot for facilitating and supporting play for children with disabilities. Our objective was to create a study design that actively engaged our participants, enabling us to gain valuable insights and information from the primary stakeholders. While we could have learned some information through focus groups or interviews, obtaining in-depth data, especially from young children with disabilities, posed significant challenges. For this reason, we decided to perform a study with co-design techniques to help engage the children and their families. When designing our study, we had to consider factors such as time constraints, children's differing physical and communication abilities, difficulty accessing participants, and the demanding nature of their school and therapy schedules.

Our first challenge was ensuring the participant feedback was grounded in the reality of what is feasible for robots, acknowledging the potential influence of exaggerated expectations by science fiction and media. Secondly, we had to determine the scope and eligibility requirements we wanted to have for our participants. The limited number of children with specific disabilities presented challenges for sample size and representation. Lastly, building bridges with the community was a crucial but challenging task we needed to face. Collaborating and establishing strong connections with the children, their guardians, and the children’s rehabilitation centre became imperative for conducting our study and recruiting participants.

By addressing these challenges, we aimed to develop a study design that effectively explored the design requirements of social robots for children with disabilities and considers the complexities of this research area. Through this research, we strived to contribute to the future development of social robots that have the potential to positively impact the lives of children with disabilities and their families.

4.1 Determining Project Scope

The first challenge we faced was setting the project scope to fit within the reasonable boundaries of a masters-level project. We originally had the idea to do a focus group with physiotherapists and occupational therapists before running a study with family units with the intent to gain initial insights for recommendations based on their experience. Conducting a focus group with professionals would help us gather information for our research questions and help us be more prepared for our study with families. Our idea was to run one or two sessions over lunch at the Specialized Services for Children and Youth (SSCY), recruiting the staff to get their perspectives about robots.

We decided against doing this for a few reasons. The first reason is many previous studies have already worked with healthcare professionals such as occupational therapists, physiotherapists, and doctors, with many even specifically doing focus groups. We felt that this data is already known and discussed vaguely in the literature. Secondly, after starting the process for ethics and working with SSCY, we realized it would most likely be a long process. Therefore, we decided that working with families would be the most impactful and should be prioritized.

4.2 Session Time and Location Considerations

Within the study, we had to consider the project's scope and the researchers' experience when making decisions. For example, we had to decide whether to do group sessions or one-on-one sessions. Given the researcher's experience and the potentially sensitive nature of our interviews, we decided one-on-one sessions would be best. Additionally, we had to consider one-day sessions compared to a multi-day session, with the family. Given the potential complexities when working with children with various disabilities and the issues that might come from recruiting for a multi-day session, having a short one day session seemed the most feasible given our setup and population.

Once we decided to do a one-day session, we needed to determine the duration of our sessions and adjust our activities accordingly to fit within that timeframe. Given our participants were young children with disabilities, we had to be considerate of how long they would be able to engage with us. Our study plan involved grounding the participants through a demonstration and eliciting their thoughts and perspectives using a co-design-inspired activity. We pilot tested our session with a pilot to allow us to make any modifications needed to ensure it would fit within our target duration of 1-1.5 hours.

Lastly, we had to consider where we wanted to run our study. We initially considered conducting the session at a booth in a public area like the front entrance area at SSCY, a fair, a mall, or the university. However, due to the potentially sensitive nature of the sessions, we determined that having a private space would be more appropriate. Additionally, we wanted to avoid interruptions from other children or families drawn to the robots and our booth if conducted in a public space.

4.3 Target Demographic Considerations

When designing our study, we carefully considered the eligibility requirements for our participants. Given our choice to focus on children with disabilities, we expected difficulties in recruiting participants and potential challenges in running our sessions with them. However, we recognized that involving their guardians would allow us to collect more valuable information and help facilitate our interaction with the child, supporting their comfort and cooperation.

We originally intended to narrow our participant scope to children with physical disabilities. However, we acknowledged the sensitivity surrounding disclosing a child's disability. As a result, we did not require families to disclose specific information about the nature of their child's disability. Without requiring them to disclose and verify their disability, we could not report on the nature of the disability of the children. Therefore, as we encountered anticipated recruitment challenges and felt a further need to prioritize inclusiveness, we realized the need to expand our scope to include a broad range of disabilities.

While we understood the importance of considering age within our analysis, we also had to navigate recruitment limitations. As a result, we determined that the participants should just be old enough (around four years old) to probably have developed verbal communication skills to enable us to collect data. We also focused on play in our study, which is more relevant and vital in the younger age groups. Therefore, we tried to find a balance by selecting participants who were both more likely to be capable of verbal conversations and young enough to have a stronger inclination towards play and where play is more prevalent and relevant for their development. However, we acknowledged that children with disabilities may exhibit cognitive abilities that deviate from their chronological age. Therefore, we decided to have a broader age range to accommodate these potential individual differences.

Though we tried to set an age limit where children would most likely be verbal, our study did not exclusively include verbal children. Though for children without disabilities, our age specification would have meant they most likely were verbal, for children with disabilities, their speech and communication skills can be delayed or hindered because of their disability. We recognized the value of understanding the experiences and needs of all children with disabilities, even those who were limitedly verbal. Therefore, we still conducted the session with them, but with the expectation that they may or may not respond to questions in the semi-structured interview. We would attempt to ask the same questions and follow the same procedure but would adapt if needed and focus more of the interview questions on the guardian. By making this decision, we aimed to consider the wide range of abilities among the participants and ensure they were properly represented.

By carefully considering these factors, we aimed to create an inclusive sample of children with differing abilities. This approach allowed us to gather diverse perspectives and insights, enabling us to learn the practical and social environment a social robot would need to integrate support children with play.

4.4 Creating Connections with the Community

It was vital for us to establish a strong connection with an established centre in Winnipeg that would not only allow us to work with children with disabilities but also be able to provide a space for our study sessions. We intended to hold the sessions at the centre to streamline the process for the participating families and make it as convenient as possible for them. Fortunately, Dr. Jacquie Ripat had prior connections working with the centre, which were invaluable in facilitating our connection to the center's activities and the larger community. Partnering with the center proved beneficial in multiple ways. It assisted us in the recruitment process, allowing us to meet and work with a diverse set of children with disabilities. It also offered an opportunity to engage with the community and gave the children a memorable experience, even for those who did not participate in our research study.

We needed approval from the SSCY centre to let us recruit and conduct our study at their center. Securing this from the center involved navigating a multi-step process that demanded careful attention to detail and consideration of ethical guidelines. In addition to getting ethics approval from the university Research Ethics Board (REB), we required approval from the SSCY center's research committee. We needed to show the significance of our research and the potential benefits for the field and the community. Dr. Jacquie Ripat introduced us and our project, helping us build trust and credibility with the center's directors. As we started the process during the spring, we encountered challenges meeting and coordinating with the center's team due to summer vacations and differing availability. Dr. James Young communicated and worked with the directors at the center to help get the approvals we needed and presented our research plan to them, helping them understand our research and its importance.

While Dr. Jacquie Ripat was familiar with the center's operations, our primary researchers were unfamiliar with its day-to-day procedures, which posed a challenge for planning and preparation for our study. To address this knowledge gap, we requested a tour of the center. We believed that learning the center's layout and daily operations would allow us to plan our study and ensure a smooth integration. However, we encountered a slight setback when the centre was unable to give a tour until we obtained ethics approval from the university research ethics board and SSCY. We understood and respected their cautiousness, recognizing the need for strict procedures considering the COVID-19 pandemic and the need to protect the privacy and well-being of the children and their families. We instead focused on securing the required approvals to run our study at the center and preparing our researchers and assistants to run the sessions.

4.5 Summary of Challenges

Throughout this section, we talked about the high-level scoping and challenges we had designing our study and how we addressed them. The first challenge in this project was to maintain perspective on its scope, considering the time constraints of a master's project. We addressed this challenge by prioritizing running a study with families, deciding to do individual sessions, and choosing a one-day format to minimize potential logistical complexities. After establishing the project's scope, we focused on determining the session duration and adjusting activities accordingly. Given the children participants would have diverse abilities, we recognized the importance of selecting a session length that would balance the time needed to gather valuable information and respect their engagement capacities. We expanded our scope of participants to include a broader range of disabilities and an age range based on the approximate age at which the child would likely have verbal communication skills and still have a strong inclination towards play. Following our project scope and participant decisions, we needed to establish connections with the center where we would conduct our study. Once we had project approval, our final challenge was navigating the schedule and procedures at the center to find an optimal way to recruit.

Chapter 5

Study Design

Work presented in this chapter has previously appeared in the following publications:

> Raquel Thiessen, Minoo Dabiri, Denise Y Geiskkovitch, Jacquie Ripat, and James Everett Young. 2023. Social Robots to Encourage Play for Children with Disabilities: Learning Perceived Requirements and Barriers from Family Units. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction, 625–628.

Based on the constraints highlighted in the previous chapter, we developed a study design that worked with a broad spectrum of children with varying disabilities. Our study started with a brief demonstration showcasing each robot to the participants to help ground them within current technical feasibility, showing what present-day robots look like and can do. Following the demonstration, we engaged them in a reflection, and then a co-design inspired activity.

This dissertation proposes to investigate the perspectives of a social robot to support children with disabilities. From this project, we would be better positioned to develop social robots for children with disabilities and do a long-term deployment in homes. We use this dissertation to understand significant factors we must consider in this design and deployment process. We present our study design to engage and elicit families.

5.1 Participants and Recruitment

Our target participants were families with a child 4-14 with a disability and their guardians. Our focus was this age group since children of this age group are more likely able to talk and participate in a co-design activity and are in the group of children where play is vital to their development. To mitigate the expected recruitment challenges, we expanded it to understand families' opinions for children of many ages and also to help us be flexible for children who cognitively might not be the same age as their biological age. We were also open to including siblings as they are also a crucial aspect of a family and might be able to provide unique perspectives on their siblings and home.

Our recruitment poster (*Appendix E*) was posted around the SSCY center, on social media, and emailed in their newsletter. Additionally, we had a recruitment booth featuring Pepper and Aibo in the front waiting area of SSCY (*Figure 5.1*). At our booth, we met the children, introduced them to some robots, and told families about our study, potentially scheduling them. On days that were slow, a researcher would walk around the SSCY center with Aibo and some posters to tell family units about our research and direct them to our booth to meet Pepper if they wished.

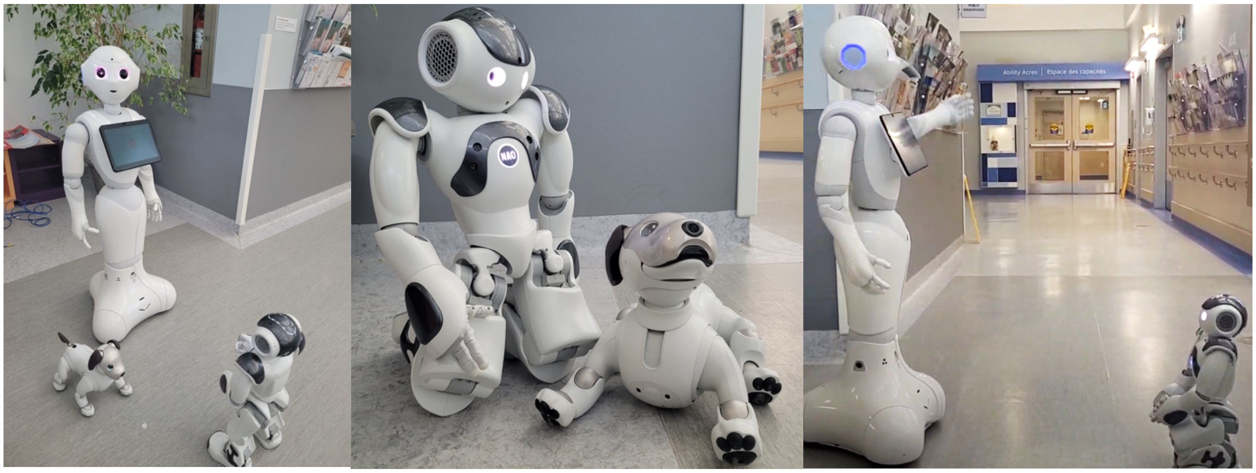


Figure 5.1 Example of our set up at our SSCY recruitment booth with the robot Nao representing the child

If participants emailed us, we would reply with predefined emails (*Appendix D*), confirming their child fit our requirements: aged 4-14 and has a disability. We did not require the child to be verbal or speak English. If they scheduled it in person at our booth, we would verbally confirm if their child fit our requirements. If they met the eligibility requirements, we would schedule their session.

5.2 Study Tasks

Our study had two primary phases: *social robot exposure* and *elicitation*, where the elicitation phase consists of three subphases: *reflection*, *creation*, and *storytelling*. We draw heavily from a priori elicitation study by Zhang et al. [6]. Below, we define our study methodology, including the different phases, their procedure, and the materials used.

5.2.1 Grounding Families within Current Robot Capabilities

To help ground the stakeholder's ideas within what is technically feasible we introduced participants to existing social robots. Our introduction gave participants an idea of current robot's appearance and abilities. To provide our participants with a more thorough view of currently existing robots, we used a variety of robots with varying abilities, both humanoid and animalistic. Based on having this experience, we believed the stakeholders would be primed to understand known possibilities and benefits, better positioning them to make judgments regarding a social robot intervention and provide grounded and realistic desires, opportunities, and use cases. This robot demonstration was approximately 10 minutes in total.

5.2.2 Elicitation

This phase focused on engaging the stakeholders in data collection that we can use to help understand our research questions. We performed elicitation through activities inspired by co-design and participatory design methods. We adapted the choice of activities per session based on the children's preferences and modified them based on their abilities. Throughout this phase, we prompted the child and other family members to get additional information on their design decisions, general thoughts, and feedback.

Reflection on Social Robot Demonstration. In this phase, we aimed to learn what the family unit (child and guardian) thinks about having social robots at home. This phase also enabled us to help participants start brainstorming before we asked them to design their robots. We did this by having the participants verbally reflect on the robots they saw by asking them questions about what they thought of them. For example, following the robot exposure phase, we would ask the child which robot they saw was their favorite, what they liked or did not like, and how they might use it. For the guardians, we asked how comfortable they would be with these robots in their homes and any concerns they would have. This phase allowed us to get a high-level understanding of the guardian and child's thoughts and helped them get comfortable talking to the researcher. For guardians specifically, asking these questions in this phase ,and then again later, helped give us an idea of how their answers may have changed throughout the session.

Creation. In this subphase, we aimed to understand the kind of robot participants believed would help encourage a child such as themselves to play. We gave the family units two options of activities for the creation task to accommodate interests and diverse abilities. They could build a physical robot prototype using our toolkit (*Figure 5.10*) or draw one using the provided paper and drawing materials. Though we did not discourage the guardian from participating in the creation, we intended this activity to be child driven. To minimize the guardians initial influence in the child's creation, we asked the guardian questions regarding their thoughts of having a robot in their home, while the child worked on creating their prototype. Following the completion of the prototype, we asked more specific questions to the child and the guardian that focused on the general physical design, the functionalities, use cases, and the social dynamics described with the robot. Using the prototype and its description by the child, we asked the guardians their concerns with the described robot interacting with their children or of it being in their home and any perceived barriers of integrating such a robot.

Storytelling. Through this exercise, we aimed to understand how children imagined themselves or another child playing with the robot, as well as the fears they might have about the robot in their home, their perception of a robot's limitations, and potential robot roles in their play or their life overall. Further, we used the creations to elicit guardians thoughts about the robot their child described interacting with their children, being in their home, or any perceived barriers to adoption and use. Finally, we encouraged children and their families to create stories using their robot design (e.g., to draw, act out, or verbally), resorting to the researchers describing scenarios of them with their robot and asking what they thought about them. For example, we presented scenarios where the robot engaged in a shared interest, such as playing soccer. We then asked the children and their families to imagine their thoughts and feelings if that were to happen. This storytelling exercise provided valuable insights into their perspectives, concerns, and potential benefits they envisioned the robot could bring in different real-life situations.

5.3 Instruments

5.3.1 Robots Used

We used a Nao Robot, Aibo Robot, SnuggleBot, and a Pepper Robot for our robot demonstrated that our described below. For physical safety reasons, the children were only permitted to touch the SnuggleBot and Aibo during this demonstration since both robots were small and did not have areas that could pinch the child's fingers.

Nao Robot. We used a Nao Humanoid Robot (*Figure 5.2*) v6 from Softbank Robotics. These robots have a football-shaped faces with lit-up eyes and a mouth, as well as arms and legs, making them look humanoid. We chose to use a Nao robot to have a smaller humanoid robot that would be less intimidating potentially than something like Pepper. The robot is 58 centimeters high and has 25 degrees of freedom, microphones, and several touch sensors to interact with the environment. This robot is not intelligent and was programmed for our demo.

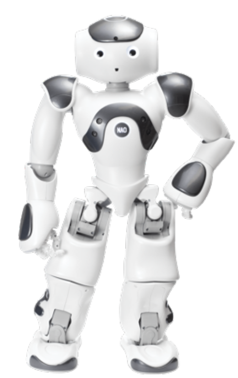


Figure 5.2 Nao robot [7]

Aibo Robot. The Sony Aibo robot (*Figure 5.3*) resembles realistic-looking dogs, with animated blinking eyes that appear to follow your gaze. Their eyes allow the robot to have social expressions, adding to

Figure 5.3 Aibo Robot [8]

its lifelike and realistic qualities. They behave similarly to real dogs, barking, wagging their tails happily, and whining when seeking attention. The robot's body has the freedom to move along 22 axes. Additionally, AI technology allows Aibo to exhibit training behaviors and appear to grow up, first acting like a puppy and then more like a fully developed dog. Built-in sensors detect and analyze sounds and images, enhancing the robot's ability to intelligently respond to its environment.

Snugglebot Robot. The Snugglebot (*Figure 5.4*) is a cuddle robot that was designed and built at the University of Manitoba. Snugglebot has a soft exterior and an internal exoskeleton that allows the arm fins and tail to move. With internal sensors the robot can detect when its being hugged and knows when it is warm. Based on its state the robot has a light up LED in its horn to display its state such as happy, lonely, or cold.

Figure 5.4 Snugglebot [9]

Pepper Robot. We used a Pepper Humanoid Robot (*Figure 5.5*) from Softbank Robotics. It is designed to interact with humans in a social and engaging manner. Standing at around 1.2 meters tall, Pepper has a curved white body with a tablet screen at its chest. Pepper is equipped with a range of sensors, cameras, microphones, and speakers that enable it to generally perceive and understand its environment. It can detect human faces, recognize emotions, and engage in somewhat natural conversations through speech recognition. Pepper's social interaction abilities are enhanced by its face tracking and

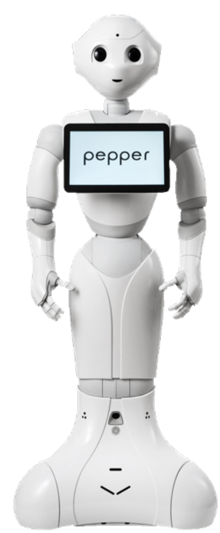


Figure 5.5. Pepper Robot [10]

continuous body movements, which help it convey emotions and engage in non-verbal communication.

We implemented a demo with the four robots discussed above. The demonstration for Pepper and Nao was programmed using Choregraphe (*Figure 5.6*), Softbank's software for programming the robots. Using Choregraphe allowed us to provide a demo using built-in behaviors and motions instead of programming them ourselves. Our demo was simple enough that we exclusively used Choregraphe. For the Nao, we had the robot speak to the child, stand up, walk toward the child, and then perform tai chi. For the Pepper robot, we had Pepper talk with the child. We designed the demo for both Nao and Pepper to give the appearance that the robot was autonomous. However, we used a wizard of oz to ensure consistent demonstrations between participants.

For Aibo and Snugglebot we used their default behaviour for the demonstration. For Snugglebot, we handed the robot to the child if they wanted to hold it and were told they could

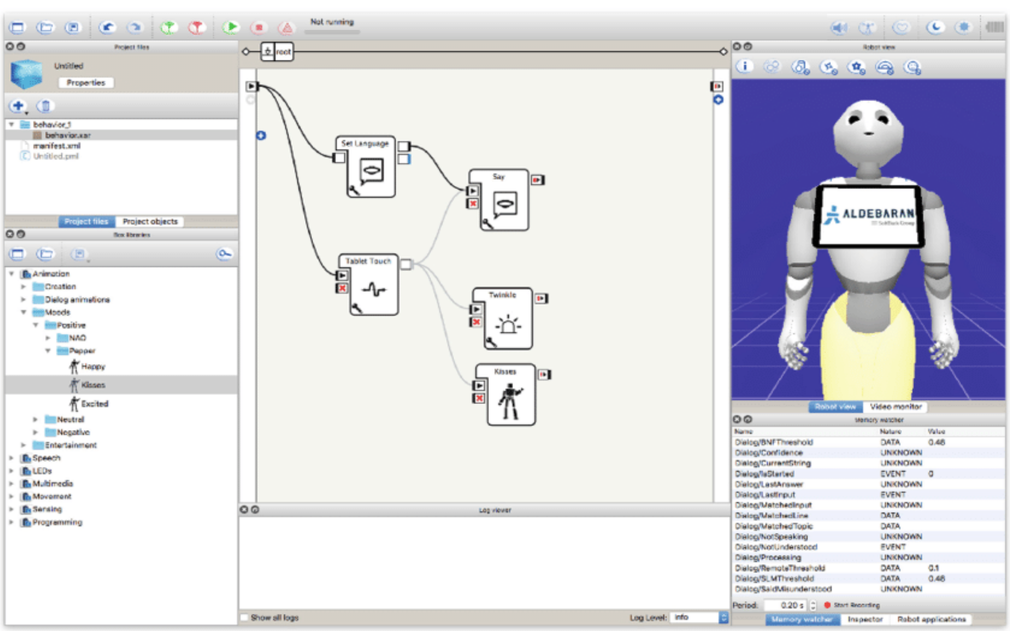


Figure 5.6. Choregraphe Software, taken from [11]

cuddle it and the robot would respond to the hugs. Aibo was just allowed to roam free, acting like a dog, walking around, barking, and responding to being pet.

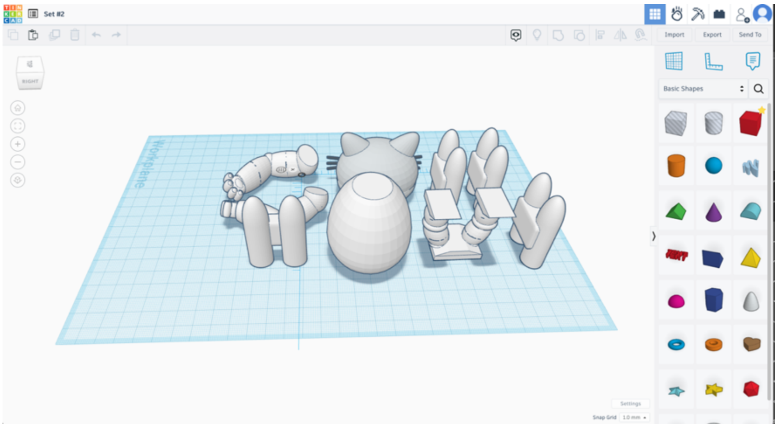


Figure 5.7 TinkerCad Software

5.3.2 3D Printed Toolkit

For our co-design inspired creation activity, we designed a build kit inspired by Robo2Box [103] and following studies [6], which had a toolkit to elicit children's design requirements. Our toolkit consists of 3D-printed pieces such as torsos, heads, legs, arms, and extra components. Considering our study would have young children with varying abilities, we wanted to design a build kit that would be quick and easy to use.

Toolkit Design. To create the individual pieces for our set, we utilized an online 3D editing tool called TinkerCad (*Figure 5.7*). We relied on previous toolkits as references to determine the components to include in our set. Finding the optimal size of the pieces, especially for easy handling by children with mobility issued, required a process of trial and error. Each piece had a flat side which allowed us to attach Velcro to each piece. In terms of object design and creation, we use multiple approaches. For some, we utilized the online library provided by TinkerCad and adjusted the component as needed. For example, we discovered an online file of a cat and modified it by removing the body, keeping just the head. We also manually created objects using the basic shapes available in the right-side panel of the tool. These shapes could be used solidly (displayed in color) or as voids within larger objects (shown with grey with lines). The tool's flexibility allowed us to meet our specific requirements and create an interactive co-design inspired activity for the children involved in our study. The Velcro attachments and various object types in our toolkit helped the usability of the set while still allowing for individual creativity.

3D Printing Process. Once we had finalized the 3D designs, our next step was to create physical pieces through 3D printing. We utilized a Dremel Digilab printer (*Figure 5.8*). The printing process began by taking the files and preparing them for printing using Dremel's slicing software (*Figure 5.9*) which allowed us to customize various printing parameters. Though we wanted to get tidied prints with minimal mistakes, we were not concerned about having perfectly printed components for our purposes since the creations were just a tool for engagement.

Figure 5.8. Dremel 3D Printer, taken from [12]

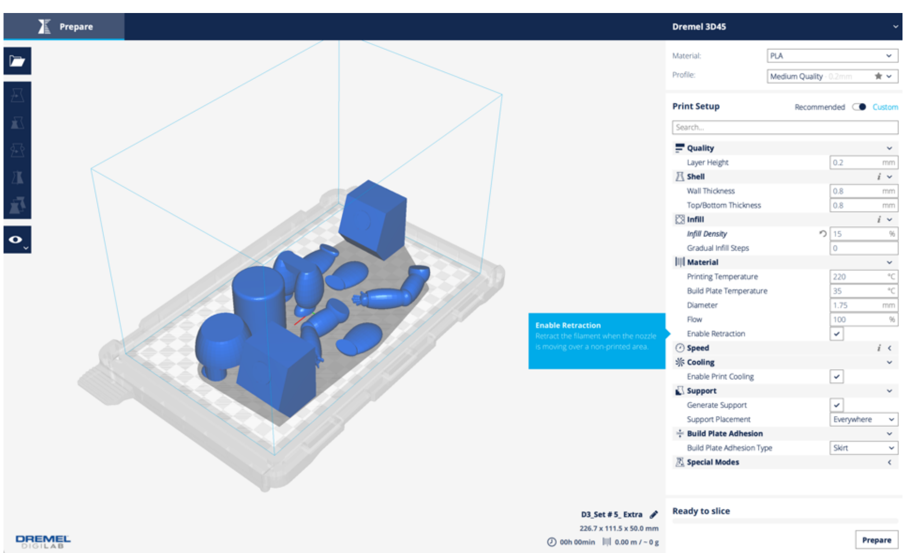


Figure 5.9 Dremel Slicing Software

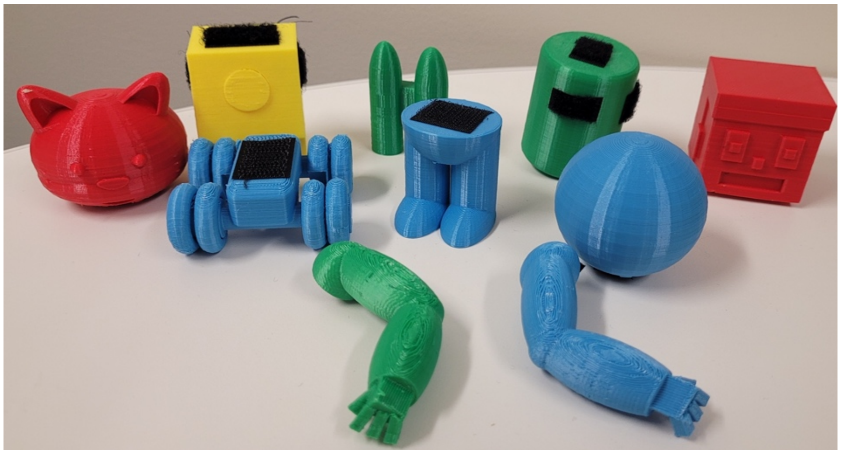


Figure 5.10 3D Printed Components

After completing the slicing process for our file, we had prepared the 3D printer for printing. Following the preparation of the printer we uploaded the files to the Dremel printer website. This platform had useful features, such as estimating the printing time, previewing of the print, and enabling us to initiate the print remotely. Additionally, the website provided a live feed that allowed us to monitor the ongoing print, enabling us to observe its progress in real-time. Once the print was completed, we removed the support structures from our 3D prints. Using pliers and files, we carefully took off the support material, leaving a complete final product (*Figure 5.10*). Furthermore, we glued the appropriate Velcro strips to the flat side of each piece.

5.4 Procedure

We conducted our study at the Specialized Services for Children & Youth (SSCY) center, a local public healthcare clinic in Winnipeg, Manitoba, that provides many services for children with disabilities and special needs. We first brought the family unit to a private room at the center to have a quieter and less distracting environment to run the study. We initially concealed the robots to minimize distractions while the researcher did consent and assent procedures. We provided the option for families to disclose their child's disability in a demographics form. They were not required to do so, and we did not conduct any confirmation of their disability, given the sensitivity of the information. The study was run in 1-1.5-hour sessions, with only one family at a time.

Our research team consisted of a primary researcher, a computer science research assistant to operate the robots, and an occupational therapy student research assistant to assist with the session. The task of the computer science researcher was to operate the robots proficiently during the demonstration, enabling the primary researcher to concentrate on the session and ensuring consistency in the robot demonstration with each family. The occupational therapy research assistant supported the primary researcher in engaging the child by modifying their approach according to the child's abilities.

Before starting the study, we obtained written consent from the guardian and verbal assent from the child. Both the child and the accompanying guardian and siblings received honorariums. The guardian received their honorarium of 20 dollars CAD before the session, and the children received their choice of 10 dollars CAD or a toy after to minimize distractions during the session. After the consent procedures, we started our study with the robot exposure task, demonstrating the four robots we brought. During the Nao demo, the robot briefly spoke with the researcher, walked toward the child, and performed a dance. The Pepper demonstration only involved a brief conversation with the researcher. The Aibo and Snugglebot were described briefly and then demonstrated their default behaviors of acting like a dog and responding to cuddling, respectively. Following this task, we moved on to the elicitation tasks. The elicitation consisted of a reflection, and creation task. We adapted based on the children's abilities as needed. For example, for non-verbal or limitedly-verbal children, the storytelling activity was less formal, and we focused our questions primarily on their guardian's perspective. Throughout the study phases, the primary researcher intermittently asked semi-structured interview questions to the children and their families to gather their thoughts and explanations of their design decisions. The study concluded based on the following: when we reached the end of our designated time slot, when we finished going through our questions, or if the child was observed by the researcher to start disengaging with the activities. Upon completing the study, the child was given the option of keeping their creation if they desired.

Our procedure and data collection were reviewed and approved by our institution’s research ethics board mentioned in the previous chapter. Complying with COVID-19 safety protocols defined by the province, the SSCY center, and the university, we used face masks throughout the recruitment and the study. Between families during our sessions and recruitment, we sanitized the area and the robots. Social distancing was maintained when possible but was not generally achievable during the session because of the room size.

5.5 Ethics

When designing a study for children with disabilities, we must address several ethical considerations to ensure the well-being and protection of this vulnerable population.

Since our study was conducted with young children, obtaining verbal assent was essential. We started by explaining what they would be doing in simplified language and ensured they knew they could stop at any time before asking for their verbal assent. With their consent, we were allowed to start collecting data. However, given that our data might include their medical information, it was crucial to take steps to safeguard the privacy and confidentiality of participants' personal information. We implemented data protection measures, such as encryption, secure storage, and anonymization, to prevent unauthorized access and maintain the confidentiality of potentially sensitive data.

Furthermore, the safety of the children was of the utmost importance, especially when involving multiple robots with young children with various disabilities. We designed the robot demonstration with participant safety in mind, ensuring the children kept their distance from the large robots and only were in physical contact with the smaller robots that did not have areas that would potentially pinch their fingers. Additionally, we prioritized inclusivity and equal access to participation by adapting study materials, procedures, and communication methods accordingly to create a supportive and inclusive research environment.

Before starting our study, we had to go through an application process with our local Research Ethics Board (REB) that made sure we had made all the appropriate ethical considerations and had solutions to address them. Following we had to get research approval from the SSCY centre.

5.6 Data Collection and Analysis

We recorded the audio of our sessions and took photos of all materials created by children in the study activities. The recordings and photos allowed us to focus on the session and let the child keep what they produced if the children desired. No photographs were taken of the family unit.

Photographs – We took a picture of each childs creation, either a robot physical prototype or a drawing. Though we were not analyzing their creation directly, we used the images to help us engage them and gain context about what the child described about their robot.

Observations – For each session, we made notes of observations throughout the session that might not have been recorded on the audio since we were not doing any video recording.

Interview Sessions – For each family unit, we conducted semi-structured interviews throughout our reflection, creation, and storytelling phases to learn their thoughts on a robot in their home, how comfortable they felt with their child using it, and any specific concerns they had. We also wanted to learn what they thought of the robot's characteristics, such as its appearance, the uses of the robot, and how a robot might fit into their homes. Sample questions from the semi-structured interview are in *Appendix F.*

Demographics Questionnaire - To obtain data on the demographics of the child with participant, we asked the child's guardian to fill out the same questionnaire during the intake and consent procedures. The goal of these questionnaires was to provide context to our data knowing the child's age, disability (if they chose to disclose it) and a bit about their family (how many siblings they have). The demographics questionnaire is provided in *Appendix C.*

Figure 5.11 Researchers at SSCY with the robots and SSCY staff

5.6.1 Directed Qualitative Content Analysis

In our qualitative analysis, we used a directed qualitative content analysis [104], [105]. The coding and theme development process in this type of analysis is flexible, allowing codes and themes to change and evolve throughout the analysis process. This approach primarily uses a deductive approach to coding our data. A deductive approach uses a predetermined code-book to ensure that the coding contributes to themes or topics related to the research questions. Typically, some inductive coding is used to produce codes reflective of the content of the data beast representing the meaning conveyed by the participants.

The process of directed content analysis involves multiple phases, which will be summarized below. In Phase 1, the researcher immerses themselves in the data, repeatedly reading and familiarizing themselves with it to identify important information. Phase 2 involves generating initial codes, which serve as the building blocks for the following analysis process. These codes are concise labels (i.e., "EB" representing explicit benefit) that capture the relevant information aligned with an emerging theme or the research questions. Systematically working through the dataset, the researcher identifies interesting or notable aspects and labels them with the appropriate codes. Directed content analysis is a recursive process that allows for continuous addition and refinement of codes as they emerge within the data. Phase 3 focuses on creating themes by interpreting the overall meaning found in the dataset. In this phase, the researcher carefully reviews and analyzes the coded data, identifying main themes and subthemes that capture the essence and underlying meanings of the data. In Phase 4, the researcher critically reviews the potential themes identified in relation to their dataset. This iterative process ensures the themes align cohesively with the data and address their research questions. In Phase 5, the researcher defines and names the themes, providing a detailed understanding of the theme's connections to the research questions. Finally, Phase 6 involves writing the paper, where the researcher synthesizes the reflexive analysis findings into a clear and meaningful narrative.

5.6.2 Qualitative Analysis

We defined our qualitative analysis plan following conducting our study but before the analysis process. We started by defining focal points (codes) under each research question we would look for within our transcripts.

Our first research question, what are their concerns and perceived barriers to adopting a social robot to support children in facilitating play? had the following focal points:

(1) Explicit concern or barrier
(2) Prior experience with tech
(3) Concern for breaking the robot
(4) Concern for impact on the child or family
(5) Concern with the child's ability
(6) Reasons for no concern

Our second research question, what are their desires and perceived opportunities for a social support robot? had the following focal points:

(1) Explicit benefits
(2) therapy opportunities
(3) Assistive for activities or learning
(4) Secondary opportunities (general play, family impact, etc.)
(5) Teaching appropriate behaviors or morals
(6) Physical characteristics
(7) Important features
(8) How they thought robots could motivate them

Our third research question, what are the specific use cases or scenarios they envision using a social robot in? had the following focal points:

(1) Use cases child-ability specific,
(2) Uses cases independent of child-ability

Lastly our fourth research question, what are their ideas on the roles the robot could take and its social dynamic with the child? encompassed the following focal points:

(1) Robot role and
(2) Child-robot social dynamic

Throughout our analysis, we refined our codes as needed and added other codes as they emerged in the data. In cases where codes were added, the researcher went back through the transcripts looking for data that fit within this new code in other sessions. Once we finished coding, we thoroughly examined the quotes, searching for recurring and noteworthy themes that emerged across the sessions. Once these themes were identified and organized, we conducted another thorough review of the data to ensure we noted any additional quotes aligned with these themes. Following, we started the writing process, constructing a result section that revolved around these themes to form a clean and cohesive narrative. Throughout the iterative writing process, we made necessary adjustments to the themes and groupings as required. Finally, we used our themes and overall narrative to derive general recommendations for future researchers designing social robots to support children with disabilities to play.

5.7 Study Summary

Figure 5.12. Pepper Greeting at SSCY

To explore how social robots can support children with disabilities in play, we designed a study to be hosted at a children's rehabilitation centre involving co-design activities with children and their families. Our main objective was to design a study that would allow us to understand the family units' perspectives on social robots to support play and the primary concerns or barriers they believe exist regarding having such robots in their homes. Our study design began by grounding participants through a demonstration of four different social robots, followed by a reflection exercise to start the brainstorming process that allowed time for the family to get comfortable talking with the researcher. Following, we did a co-design activity with children with disabilities creating robot prototypes using our 3D printed toolkit or drawing materials and facilitated discussions on their opinions, needs, wants, and concerns. Through directed content analysis, we used our data from the discussions with family units to identify primary themes and derive recommendations for designing social robots that facilitate inclusive play for children with disabilities. We present our findings in the following section.

Chapter 6

Study Results

In our study, we focused on exploring the perspectives of families with children with disabilities to learn what concerns they had regarding a social robot in their home, how they imagine the child might play with it, and what role and social dynamic they believe the child would have with the robot. The participant data we collected helps us answer our fundamental research questions and to move toward developing recommendations for future work designing social robots for children with disabilities to support them with play.

Using the study procedure outlined in the previous section, we recruited eight family units at SSCY who participated in our study. All participants engaged with our activities, with seven children choosing to use our build kit and one child choosing to draw. Though not all the children were fully verbal, seven of eight children with disabilities engaged in at least some discussion with their guardians and the researcher. This section will discuss about the results from the data we collected that help us answer our fundamental research questions and to move toward developing recommendations for future work designing social robots for children with disabilities to support them with play. Below we outline the dominant themes from our qualitative analysis and present the resulting recommendations and considerations.

6.1 Participants

We recruited eight groups consisting of eight children participants with a total of 1 accompanying sibling and eight guardians interested in participating in the study (Table 1). Out of the children with disabilities who participated, five children were female (mean [age] =7.5, SD=2.87). The tables below describe the group demographics and children's disabilities as disclosed on our demographic questionnaire.

TABLE I.

Family-Unit Participants

Family Unit	1	2	3	4	5	6	7	8
Child	C1	C2	C3	C4	C5	C6	C7	C8
Guardian	G1	G2	G3	G4	G5	G6	G7	G8
Sibling					S5			

TABLE II.

Participant Demographics

ID	Gender	Age	Disclosed Disability
C1	Male	5.5	ASD and ADHD
C2	Female	11	social and communication issues
C3	Female	3.5	issues walking and balancing
C4	Male	6	ASD
C5	Female	11	intellectually disabled, apraxia of speech, issues walking
C6	Male	9	limited range of motion and unable to walk
C7	Female	5	paralysis of legs with minimal recovery

C8	Female	9	undisclosed

6.1.1 Recruitment

We faced difficulties recruiting children for our study as a limited number of children fit our age specifications and had their guardians consider the child to have a disability. We aimed to recruit 10 -15 families. One of the specific challenges we encountered was the scheduling conflict with our target age group, as they typically had morning appointments and attended school afterward. These children would leave the center immediately after their appointments to go to school, and their guardians would need to return to work. This scheduling issue posed a significant obstacle to our recruitment efforts. Compounding our recruitment issues was our inability to schedule appointments after school or on non-school/non-workdays due to the limited opening hours of the center.

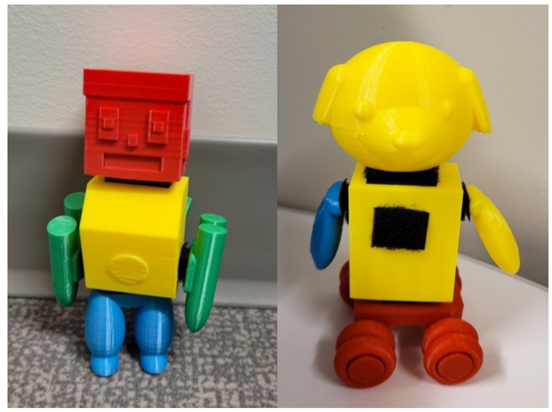


Figure 6.1. Child Creations from our co-design activity in our study

It also took us some time to adapt to the schedule of our target population and find the most effective strategies for recruitment. We were initially unaware of the setting and environment of SSCY, which made it difficult to determine the best recruitment method before being at the center for some time. When we first started, we walked around the center to put up posters and talk to families while carrying the Sony Aibo and telling them about our research. After minimal responses through these methods, we changed our approach to a booth in the lobby with the Pepper and Sony Aibo robots. We also observed that the center experienced peak activity only until 2 PM, after which the foot traffic significantly decreased. Overall, we spent 114.5 hours at the center, over 25 trips (including packing and unpacking, setup, etc.), with

100 hours dedicated solely to recruitment. Though we had a lot of families meet with the robots and check out our booth, very few agreed to do the study.

6.2 Qualitative Analysis

6.3 Results

The data analysis process involved examining the audio recordings, as outlined in section 5.6. There was 6.5 hours of audio data that was transcribed by the primary researcher. Additionally, the participants in 8 groups created original robot designs (e.g., samples shown in *Figure 6.1* and *Figure 6.2*). It is important to note that these creations were not the primary focus of our research questions but were used to engage and facilitate discussion and provide a visual aid for storytelling. Therefore, we do not analyze the actual creations in this paper.

While we did not conduct a specific analysis of the creations produced by the children, we will provide a brief overview of the outcomes of the activity and the children's designs. We used co-design activities to engage the child and their family in exploring the potential of social robots to enhance play experiences. Seven children used our 3D-printed toolkit, and one drew for this activity. The children showcased a variety of creations, generally aligning with their verbal descriptions. For instance, those who described their robot as appearing like a cat or dog robot incorporated the appropriate head in their designs. Children who wished for their robot to walk alongside them used leg components, while those who envisioned racing their robots (like one would in a wheelchair) opted for wheeled pieces. Notably, throughout the discussion segments of the activity, if a component appeared inconsistent with their desires or description, the children would adjust their designs, finding more suitable pieces without any prompting. Though the child was the one who made the creation, their verbal descriptions and conversations with researchers often lead to the guardians making additional comments the guardian or child did not mention originally.

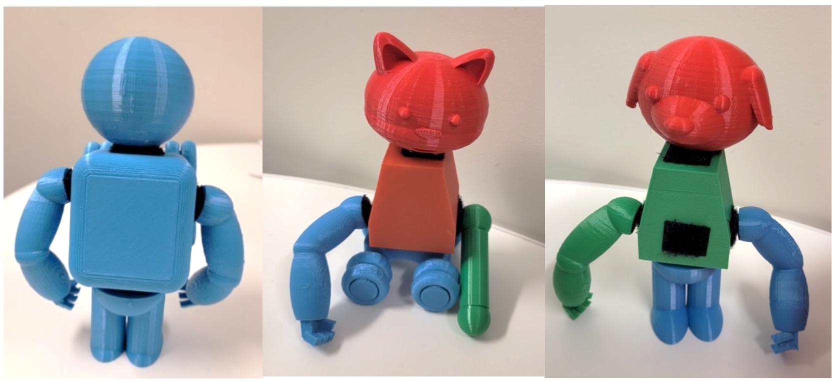


Figure 6.2. Child Creations from our co-design activity in our study

6.3.1 Robots as Companions

Families commonly discussed potential roles that social robots could play in the lives of their children and families, showing families openness to a social robot intervention and providing potential design vectors for novel robotic technologies to support play. For example, multiple family units (3) described a **robot that would act as a companion**, giving the child "someone to talk to" (*G6*), play with and spend time with. They described a robot that could serve not only as a source of emotional support, but also as, providing companionship and comfort.

One child explicitly talked about how the robot could help them:

> *"I think what I would like to do would be like play with her or she can like help me make friends" – C2*

Similarly, in multiple family units (5) the child and or the guardian described a **robot that would act like a pet** their child could play with; for example, some children specifically said they felt this robot would be more like a pet (*C1, C6, C7, C8*), or that they would like to take care of it like a pet (*C6, C7*). Guardians (*G4, G6*) reflected on using a robot for children who cannot have pets to gain experience and learn:

> *"He has always wanted a pet but there are restrictions of what he can do, where he can go…. Knowing that he can train it to makes it feel like he isn't missing out on the feeling, so when he is older, he can transfer his knowledge with a real dog."*
> *– G6*

Along the same thread, families commonly mentioned the potential of the **robot to provide emotional support**, suggesting that a robot could help their child calm down (*G4*), *"*should put them in schools because there are a lot of kids who are very sad and lonely*"* (*G2*) and that:

> *"Maybe she can help me if I am sad or mad" – C2*

> *"Yeah, if I am sad, he could walk to me and give me a hug" – C7*

More generally, children and their guardians broadly discussed the potential for social companion **robots to support children's existing interests and hobbies** and related activities. These activities included playing sports like soccer (*C1, C2*), football (*C1*), basketball (*C2*), volleyball (*C2*), and gymnastics (*C7*). Additionally, some families envisioned the robot participating in artistic activities such as singing (*C1, C6*), dancing (*C6, C7*), building (*G4*), and role-playing (*G4, C7*). Two guardians also expressed that they believe their child would enjoy having a robot that would read to them (*G3, G4*).

Both children and guardians (*6 family units*)**,** stated that the child **would primarily prefer to play with their robot alone** or only with a family member they are close to. A few children said they would want to play with the robot specifically at home, adding they would primarily only play with their family members (2 children). Two family units provided potential explanations, pointing out that their child may have this preference due to their specific circumstances, such as the child currently primarily plays alone, or their child does not have many friends:

> *"His friends are mainly in school not so much outside of school" – G6*

> *"She tries, she struggles to connect. I think she would love to play with anybody… her peers generally lack the patience to play with her for anything more than a couple minutes if they are willing even to do that and that's hard, it is." – G5*

For 2 of the family units the child specifically expressed sharing their robot with others outside their family unit with one child saying:

> *I like to share a lot! … I'm going to make sure they all get a turn, that who everyone wants it and I'm going to make sure nobody gets left out – C7*

Thus, both guardians and children are receptive to social robots, conceptualizing them as companions or pets and open to the idea that can provide emotional support, or support children in their interests and hobbies (families open to the idea of a robot providing emotional support). There is uncertainty perhaps regarding whether families believe that such robots would be for solo play or for supporting children to play with others, but overall, these results are promising from the perspective of gauging families' willingness for a social robot for play. Further, these results indicate potential design avenues for a play-support robot that may be readily accepted or understood by families, for an example, as a pet or a hobby support robot.

6.3.2 Robots as Motivators and Therapy Support

Despite the study focus on play, guardians often talked about the potential for social robots for more immediately pragmatic purposes. For example, guardians reported envisioning **robots helping to motivate their children to engage in tasks**, such as promoting their child's group participation (*G4*), speech (*G1, G3, G4, G5, G8*), and motor skills (*G3, G4, G5, G6*):

> *"Right now, our main concern with her is her communication skills are very, I think I told you she has apraxia of speech, so something that coaxes her to speak clearly would definitely be helpful" – G5*

> *"So, if he had something that sort of made it fun... something that would encourage him, like why don't we do this and then we can go play this or something like that" – G3*

One guardian specifically saw the robot as a way to encourage outdoor play:

> *"After the covid and everything kids are like glued to the TV... it's not good for them, too much computer, too much TV... if they take it out the robot can socialize with people" – G2*

Conversely, another guardian was concerned they would have difficulties getting their child to stop playing with the robot to go outside to play (*G7*).

Some families (*2 guardians and 1 child*) tended to talk about **service robots that provide disability-related assistance**. For example, one child who was in a wheelchair talked about having a robot that could help them reach and bring things that they would not be able to reach on their own (*C7*), and guardians talked about a robot that could notify them when the child needs help (*G5, G7*).

> *"She has little like seizure like symptoms in the past so if a robot could sort of tell us ahead of time that's coming" - G5*

Several guardians (*3*) expressed potential advantages of utilizing a social **robot for physical therapy**, serving as a source of motivation for children to engage in exercises and could be used to imitate movements to assist their child:

> *"Say if it's like humanoid watching how they walk or demonstrating something… something that would demonstrate would probably encourage her to do it as well" – G3*

> *"Maybe if it could demonstrate kicking or throwing" – G4*

Similarly, guardians noted that the robot could potentially assist the children with **speech therapy and communication**. For instance, one guardian mentioned that the robot could be beneficial in supporting their child's speech pronunciation:

> *"Definitely with the speech, so, it's like if something could you know that's what she is trying to say and then just say it, like that's what I do I repeat it the right way" – G3*

One family unit with a non-verbal child discussed the potential of utilizing a robot as a tool to aid in the development of their child's communication skills:

> *"At school he has a tablet that has different pictures so he can point to things to help him communicate so if the robot was saying like hi how are you and waving and stuff that might help with his communication skills" – G4*

More generally, guardians (*G2*, *G3, G5, G6, G8*) noted potential for a social robot to help with education, for example, helping with schoolwork:

> *"Uhm if there is one that could uh maths for example or spelling words, let's try spelling this, so it's kind of like fun learning" – G6*

Or learning a new language:

> *"Speaking French because he is in French immersion, we don't speak French at home so once he is at home it's not there right" – G6*

Thus, families envisioned robots could serve a wide range of roles, such as providing motivation and assisting with therapies and schoolwork, allowing for further opportunities for applications of social robots in other domains.

6.3.3 Disability Related Considerations

There was a dominant theme of needs particular to the children living with disabilities. For example, some parents noted issues with overstimulation, and thus care needs to be taken for **acclimation to the robot (3)**. This includes having time to adjust to the robots before children would really engage and play with them.

> *"She acclimates but just is very slow, overstimulation is a big issue with her." - G5*

> *"He is a bit shy... some things he just takes a little bit of time to warm up to, but I am sure with time he would end up playing around with the robots." - G4*

These results correspond with researcher observations during the demonstration task, where some children were observed to be initially hesitant with the robots, but over the course of the session, they gradually grew more comfortable with playing, touching, and being around the robots.

There was some discussion around considering the design of the robot to manage acclimation, particularly around the **importance of the robot appearance.** Families felt that the robot should have a friendly appearance, with a soft voice and soft features (*S5, G3, G5, G7*). Some participants also mentioned having a robot with animalistic features specifically can be helpful to be less intimidating as they are more familiar for children, potentially leading to children being more willing to play with it (*S5, G3*). While much of these considerations will be important for any child, given the raised concerns over challenges with stimulation and change, they may be particularly key for children with disabilities.

Related to this, there was some discussion on the use of **robot characterization**, that is, the introduction to the robot and its characteristics (e.g., personality and appearance), which may help and support adoption. For example, one child talked about how they believed one reason it might be hard for a child to play with a robot is if they fear it (*C2*). This child suggested that a solution to this problem would be to give it a personality (*C2*). They further followed this up by saying that the most important feature for their robot was for their robot to have emotions (*C2*).

Families thus were concerned over the initial adoption and potential challenges faced by their children who may have difficulty with overstimulation and change, noting that both the robot design in terms of comfort, as well as how it is characterized to children, may be helpful in facilitating overcoming this initial barrier. These considerations are crucial for the successful adoption and integration of social robots for play and for ensuring that children feel comfortable and engaged in playing with the robot.

Children did not express concerns or considerations related to their disabilities, such as emotional well-being, environmental factors, or physical limitations, unless prompted by their guardians. Even when prompted, their discussion about these considerations were minimal.

6.3.4 Child Well-Being

The social nature of companion robots raised concerns about child emotional considerations and the impact on their social interactions.

Potential Impact on Emotional Well-being. Guardians expressed concerns about secondary impacts of their child bringing their robot into public places. For instance, one guardian mentioned that having their child's robot at school or in public might cause their child to feel "protective of it and maybe overwhelmed" (*G4*).

Attachment and loss. One guardian shared how their child might struggle with other children playing with their robot, mentioning that their child has been possessive but that she has gotten better with attachment and loss (*G5*). Another guardian expressed concerned their child might lose the robot if brought into a public place saying:

"He definitely likes to take his toys with him which some ways is good, some ways is bad... because it can get lost... even with the cheap transformers as soon as the joints broke he gets upset" – G4

6.3.5 Safety and Environmental Considerations

Finally, the primary concern raised overall in our sessions regarding a companion robot to support play was safety for the robot and the child. Four guardians briefly expressed concerns about children's physical safety, citing potential risks such as their child's fingers getting caught in the robot (*G1*), the possibility of electric shocks (*G6*), or the risk of a larger robot falling and causing harm (*G5*). On the other hand, some expressed confidence in the safety of the robots, given what they saw in the exposure phase, due to the robots' programming and physical appearance.

"Looking at the robots everything checks out for me like because they are safe" – G2

In contrast, families expressed a much broader range and depth of concerns about the **safety of the robot** relating to the possibility of their children breaking or damaging the robot, than safety for their children (*5 guardians, 1 child*). For example:

"R: Would you have any concerns with her and the robots, for example if she was playing with it in the living room and you were in the kitchen

G3: uhm getting too close to the stairs, falling down the stairs

R: do you mean the robot or her?

G3: well, I haven't seen her do it, I think she is more aware... but I would hate for her to get too close that the robot would break"

Researchers directly observed this during the study, for example, guardians repeatedly reminded their children to be gentle and careful when interacting with the robots (*G3, G8*). Another guardian mentioned their child can be destructive and they were worried the robot being mistreated or damaged (*G7*). When asked what would be important to consider for designing a robot for their children, guardians emphasized the durability (*G4, G7*). One guardian explicitly said they would be nervous about leaving the robot alone with their child due to the cost:

> *"R: yeah, would you be comfortable with for example Aibo, the little dog robot, leaving her alone with it?*
> *G5: I think I would feel more comfortable if she had someone around with her, I don't know if I feel good about her being alone with it, because I'm sure it's not a cost, not a cheap item"*

Additionally, one child also had concerns for the safety of the robot, saying that when the robot does summersaults with her the robot would need to do it on her mat like she does so *it* would not get hurt (*C7*).

More broadly speaking, two guardians used language surrounding **comfort with AI**, saying, "Uh so you have total control of the robot? No AI haha… for me yeah, the unknown is a little uh you don't want too much of the unknown but yeah as long as it's safe it would be just fine" (*G8*) and saying though would be especially worried depending on the technology the robot would do something weird if it was self-aware (*G5*). Some guardians expressed that they were not particularly concerned about the technology itself, stating "I'm not too fixated on iRobot" (*G1*) and "Well, sci-fi movies talk about robots taking over but that's all silly" (*G3*). We had no participants raise issues relating to privacy or security in their homes.

Safety is a crucial factor to consider when designing social robots for children with disabilities. It is essential to address both the safety of the child and alleviate concerns or worry that families, especially guardians, have regarding the safety and mistreatment of a potentially costly robot in their homes. By prioritizing safety in the design process, we can create social robots that provide a secure and comfortable interaction environment for both the child and their family.

6.3.6 Domestic Environmental Concerns

During our sessions, it became evident that several families preferred smaller robots in their homes, as the primary concern revolved around the potentially intimidating nature of larger robots that might lead to children being timid (*G3*) or fearful (*C7*). Additionally, another guardian pointed out that a large robot could be intimidating for their child.:

> *"Something that in my mind is too big would be an intimidating factor... I'm not sure if she would let the humanoid robot (pepper) get any closer to her than what we did" – G5*

One guardian mentioned they preferred a smaller robot due to the size of their home:

> *"What we are more worried about is space because we live in an apartment, that one (pepper) might not fit in it" – G5*

In contrast, a guardian mentioned the potential need for a larger robot due to the kinds of functionality or support they envisioned, stating that if the robot lacked the capability to pick itself up after falling, her child would face difficulty in assisting it since he cannot reach a small robot from his wheelchair (*G6*).

Families expressed both emotional and practical concerns regarding the size of the robot. While there was a general preference for a smaller robot, it is important to consider the specific environment restrictions of each family and their individual usability needs when determining the appropriate size of the robot.

6.4 Discussion

We gained valuable insights and knowledge at every stage, from study design to data analysis. In the following section, we reflect on what we learned, summarize our findings, and provide our interpretations.

As an exploratory study, we aimed was to establish a foundation for future research on social robots that support and encourage children to play. During our sessions, we successfully engaged with families, fostering meaningful discussions and gathering their perspectives on the considerations involved in designing a social robot for children like theirs. Many families expressed excitement about the potential of social robots to assist and play with their children. Their excitement was potentially additionally heightened since it was the majority of their first experience with real robots. Overall, we observed the openness of families within this community to have social robots to support their children.

Most of our family units comprised one guardian and one child with a disability, but one family had an additional sibling. Given our choice to allow additional family members, we were prepared to be flexible in our methods to include the other family members. In this particular case, the sibling actively participated throughout the study, assisting with engaging their sibling who was living with a disability in our activities and with discussions with the researcher. They also shared their thoughts about having a robot for their sibling and in their home.

While our focus was on their perspectives about play between their child and a social robot, guardians also discussed considerations regarding the child's adaptation to the robot and its integration into their home environment. Interestingly, the children did not generally express significant concerns or barriers related to their disabilities affecting their ability to play with the robot unless first brought up by their guardians. Nevertheless, these aspects are crucial for designing a social robot that can seamlessly integrate into the child's home and cater to their individual needs.

Guardians frequently emphasized the practical applications of social robots, such as aiding with homework or therapy. This coincides with existing literature that emphasizes that children with disabilities often have more time prioritized for therapies, potentially leading to fewer opportunities for play [18], [19]. The children in our study, expressed more interest in using the social robot for play and perceived the robot as a pet or companion. The guardians supported the children's ideas, with some recognizing the potential for a robot pet to teach responsibility and offer an experience similar to having a real pet, which may otherwise be inaccessible. Although our research primarily centered around play, exploring the additional desires of these families for a social robot enabled us to identify avenues to pique their interest and enhance acceptance. By considering these diverse perspectives, we can develop social robots that not only cater to the needs of children with disabilities but also align more closely with their expectations.

While our primary focus was on social robots to support play for children with disabilities, future research should also explore and consider the potential influences and effects of non-social robots in this context. Non-social robots have the potential to complement social robots, resulting in a more diverse and inclusive play experience. Combining their distinct capabilities could lead to well-rounded and engaging playtime for children with disabilities. Future research should investigate social and non-social robots and how they can be integrated and utilized effectively based on individual needs and preferences.

During our sessions, we observed a progression of ideas among our participants as they interacted more with the robots and engaged in discussions with the researcher. We also noticed dynamic interactions between the children and their guardians during the discussions. In some cases, the children would describe their ideal robot or how they envisioned using it, and this would spark additional thoughts and changed opinions from their guardians. Furthermore, we observed that children would refine their descriptions and creations of their envisioned robots. As they visualized the robot in their lives, some children realized that their initial design did not entirely align with their preferences or ideas. This self-correction process allowed them to fine-tune their creation, creating a clearer vision of what they desired in their ideal robot companion. Understanding this progression of ideas and the influence of discussions is valuable in guiding the development of more meaningful and personalized social robots for children.

6.5 Recommendations

In this section we will briefly talk about each of these recommendations and considerations and ways they potentially could be applied.

Design a play social robot with a familiar form. While this is true for numerous children, it is particularly relevant for children with disabilities who may require additional time to adjust to new circumstances. For these children, having a social robot that takes a form the children are familiar with and comfortable with can allow for a smoother transition and potentially make the robot less intimidating, as suggested by our participants. Further, previous research has theorized that allowing children to choose their robot characteristics might allow for increased child-centeredness in the interaction ("build-a-bear" concept) [106]. Given our data and previous work, we think that possibly having a child with disabilities choose a form for their social robot that they are comfortable with could help with their acclimation.

Incorporate individual children's hobbies and interests in robot design. By incorporating individual children's hobbies and interests into robot design, we can enhance their engagement and facilitate adoption. Families in our study suggested various activities that children already enjoy, such as sports, arts, and games. Instead of focusing solely on specific activities, these suggestions emphasize the potential of aligning the robot's capabilities with their interests to capture their attention and encourage adoption. Complex technical implementation is not always necessary. For example, a robot coach that runs skill drills, facilitates learning, and motivates them to play a sport instead of playing it with them could be more feasible but still effective. For children with disabilities, who often struggle with engagement and motivation, a social robot that even indirectly participates in their hobbies may increase acceptance and adoption. This alignment creates a bonding opportunity and encourages participation in other activities they might typically be less interested in. Moreover, we can draw upon existing play interventions as a guide for integrating the robot into children's play, such as incorporating the robot into playdates, utilizing modeling techniques, or positioning the robot as a play facilitator.

Consider the integration of the robot into other parts of their life. Though our research focuses on social robots for supporting play, families, especially guardians, showed a desire for social robots to contribute to therapeutic efforts such as physical therapy and speech therapies, and educational efforts. Adding some support for these additional efforts would not only potentially benefit the child, but given a wide range of functionality, might help with acceptance and adoption by families, as this was a desired ability raised by multiple guardians. Integrating new things can be difficult for children with disabilities. However, as stated by some of our participants, if the social robot has clear benefits, families might be more willing to put in the effort to integrate it.

Emphasize the robots' robustness and downplay fragility and cost. One of the primary concerns consistently expressed by families throughout our sessions and even during our recruitment process was the fear of their child breaking or damaging the robot. While this may appear trivial, we observed that these concerns had a notable impact on the behavior of both the guardians and the children. The guardians' worries often resulted in them instructing their children to be extra cautious, influencing their interactions, limiting their natural engagement with the robot, or even completely stopping them from interacting. To address this, we can build a more robust robot, but it is also essential we demonstrate and emphasize its durability. By reassuring families about the robot's resilience, we can alleviate worries and hopefully encourage a more relaxed and natural play experience. Additionally, considering the families' perceptions of the high cost of the robot, downplaying the robot cost can further alleviate these concerns.

Child's Emotional Needs. While our primary focus was social robots for play, we must also be aware of and consider the related potential emotional impacts and implications. For example, guardians highlighted concerns regarding their child bringing the robot into public settings, as it may draw attention to their child and potentially overwhelm them. They also expressed worries about their child's emotional response if the robot were to be lost or taken from them. Though we might not be able to address all of these concerns directly, it's crucial to consider them when designing a social robot and make adjustments to minimize the impacts where we can. Families also discussed the positive potential for the robot to provide comfort and emotional support to the children. Children with disabilities often undergo challenging medical procedures, appointments, and therapies, which can cause stress and anxiety. Previous research has shown the effectiveness of social robots in alleviating children's pain, stress, and anxiety [107]. Considering the desire by family units and the known benefits, incorporating the capability for basic comforting and emotional support would probably be a valuable feature, even for a robot primarily intended for play.

Considerations for the social aspect of play. Similar to the literature, our data showed that children with disabilities expressed more preference for solitary play over parallel or collaborative play [108]. Therefore, when designing a social robot, it is crucial to focus not only on promoting and facilitating collaborative play but also on providing support for individual play. By acknowledging and accommodating the diverse play preferences of children with disabilities, we can create a social robot that effectively engages and caters to their social needs during play experiences.

Our research aimed to learn the structural and social challenges to consider when designing social robots to support play for children with disabilities effectively. Furthermore, we aim to explore integration opportunities that would help with the acceptance and adoption of such technologies. The recommendations we provided serve as design guidelines, offering researchers valuable considerations for designing social robots for children with disabilities, with a focus on promoting acceptance and adoption. These recommendations reflect our core research questions and shed light on aspects that need to be considered, such as the concerns of families and the barriers to adopting a social robot, the desired use cases and the needs of the children, and the role they imagine for the robot and the social dynamic between the child and the robot.

6.6 Summary

In this chapter, we presented the results of our study focusing on learning the perspectives of families with children with disabilities about social robots to support play. To address our research questions, we conducted a thorough analysis of the data collected during our sessions, leading to the identification of several key themes: robots as companions, robots as motivators and therapy support, disability-related considerations, child well-being considerations, safety and environmental considerations, and domestic environmental concerns. We then used this information to help us make guidelines and recommendations for other researchers. Future work can use these recommendations to design and create a prototype to investigate how a social robot can support children in play.

Chapter 7

Limitations and Conclusions

In this research, we investigated the perspectives of children with disabilities and their families on a social robot to support play. We found that people saw the potential of social robots in their homes to support their children by being a companion, participating in their interests, and providing support for various therapies. Developing social robots that fulfill the needs of the children and their families and can adapt based on the child's abilities will be crucial for the success of their adoption. In the previous section we described our preliminary results with considerations for designing a social robot to support children with disabilities. This work provides background to move forward building and deploying actual robots to support children for play.

In the final section of this dissertation, we will discuss the limitations of our work and briefly discuss the future research needed to understand more concretely the issues they might face for adoption in their homes and other considerations that need to be made.

7.1 Summary and Contributions

The work presented in this dissertation provides a range of contributions reflecting on our primary research questions. In this work, we wanted to understand the perspectives of family units with children with disabilities regarding concerns they would have with a social robot for play in their home, barriers there would be for adoption, the potential use cases, and the role and social dynamic between the robot and their child. Through our study to understand these research questions, we made the following contributions:

- high-level guidelines to consider when designing robots for children with disabilities
- presenting stakeholder data on pre-adoption, perceptions, desires and more
- presenting a feasible study design for elicitation with children with disabilities
- supporting the local community by providing enriching experiences and opportunities to engage in

The first contribution is the noteworthy themes we extracted from our data and the initial high-level guidelines and recommendations we developed for future researchers. These guidelines serve as a starting point for future researchers to study social robots for children, providing them with practical insights and directions for further investigation.

While our research represents an early stage in understanding the challenges related to the design and adoption of social robots for facilitating play, our contributions lay a foundation for future work in this area. We acknowledge the need for further research to gain a more direct and practical understanding of the utilization of social robots in play interventions for children with disabilities. Nonetheless, our study contributes to research emphasizing the importance of actively involving stakeholders and utilizing co-design techniques in research processes.

Our approach of involving family units of children with disabilities through co-design activities is also a notable contribution. Though there are challenges when working with a vulnerable population, this method gave us a grounded understanding of the specific requirements and design specifications for social robots to support play for children with disabilities. The involvement of family units added a real-world perspective to our research and allowed us to gather nuanced insights that may have been overlooked or not considered otherwise.

Lastly, we engaged with the people in the SSCY community, allowing the children and their families to interact with real robots and share their valuable perspectives, contributing to designing technology for others like them. This connection we built with the community as well as the clinicians helps pave a path for future work with this community for future research.

7.2 Limitations and Future Work

Drawing from our sessions with stakeholders allowed us to form preliminary recommendations for designing social robots to support children with disabilities and highlighting a range of potential future directions for research in this field.

For future research, it will be important to expand our initial feasibility study to have more participants. While our small sample size is sufficient for our exploratory focus, expanding our sample with more children will increase generalizability and allow us to create more robust and nuanced design recommendations. Further, while we focused on the general category of children with disabilities, future work will need to consider the specific needs and challenges faced by people with different circumstances. For example, children with cognitive delays might have different considerations than children with physical disabilities. Another way to do this would be to recruit more based on specific age groups and disability types, verifying children's disabilities, so our findings can be more specific for children with different needs. In our study, we deliberately took this approach to help gain the trust of the center and community by prioritizing privacy and inclusivity. However, this knowledge can allow for subtle design changes to ensure that social robots meet the diverse needs of children.

Our work should be supported by doing a focus group with physiotherapists, occupational therapists, and engineers that work regularly to make adaptive technologies to add to our initial recommendations. Doing a focus group with professionals would help us gather more information for our research questions from their perspectives. Even though past research often uses focus groups or consultations with professionals for their prototypes, the actual data from the professionals is often not published in detail. Information that would be particularly important to learn from them would be about the barriers they imagine for children with disabilities using robots and potential functional or technological solutions for addressing these issues. Having a study that more directly talks about their perspectives and develops recommendations from their data could be helpful for future research.

Future research could work on designing social robots to support children with disabilities in play using our recommendations and other literature. Following the design, researchers could implement the robots and investigate the adoption process and any issues that might arise. Deploying social robots in real-life home environments in this way would provide valuable insights into the factors crucial for successful adoption and highlight additional considerations that may have been overlooked.

Despite our limitations, we successfully engaged children and their guardians during our sessions. The families we worked with even showed enthusiasm regarding the potential for using social robots for children with disabilities. However, further research is still necessary to fully implement social robots to support children with disabilities in play. This initial research provides insights for future designs, emphasizing the importance of the adaptability of social robot designs to meet the individual needs of each child. Overall, our research emphasizes the importance of continued inquiry and exploration in this area and reveals the potential of robots in supporting children's play.

7.3 Conclusion

In conclusion, this dissertation contributes to the field of human-robot interaction by exploring the unique needs of children with disabilities and engaging with families in the community. Through our research, we have gained valuable insights that can inform the design and development of social robot prototypes tailored to meet their expectations and enhance their play experiences. Our work adds to the existing body of knowledge and provides a foundation for future explorations and research in this area.

Play is a vital aspect of childhood development, and our research highlights the potential of social robots in promoting and enhancing play experiences for children with disabilities. Understanding the concerns and preferences of families is crucial for addressing adoption issues and ensuring that these technologies can get into homes and benefit children. We envision a future where social robots become accessible tools that promote play and contribute to the well-being and development of all children. We hope our work helps show the importance of further inquiry for social robots supporting children with disabilities.

Appendices

Appendix A: Guardian Consent Form

Project Title: Re-thinking Social Robots for Children with Disabilities: Learning from Family Units
Primary Researchers: Raquel Thiessen (Masters Student), Dr. James E. Young (Professor), Dr. Jacquie Ripat (Associate Professor)
Research Emails: thiess83@myumanitoba.ca, young@cs.umanitoba.ca, Jacquie.Ripat@umanitoba.ca
Researchers in Attendance: Raquel Thiessen (Masters Student), James Berzuk (Research Assistant), Nathan Lo (Research Assistant)

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with others before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Study Purpose:
You are invited to participate in a research study on the topic of collaboratively working with children with disabilities and their families on designing social robots. This study will take place at SSCY where you and your child will meet some real robots and then work collaboratively to design a robot they could play with. The goal of this study is to learn what children with disabilities would need and look for in a social robot for play. Your participation in this research study involves working with your child on drawing or building a robot model and creating some stories about how they would use their robot. If you have any questions or concerns, please feel free to contact the researcher at the above email address.

Study Procedure:
Your participation in this study will take approximately 60-75 minutes. Before participating in the session, you have to sign this consent form. An overview has already been verbally explained to you and is further outlined in this document. We will start with a brief demo with real robots and then we will go through a creation process to have your child design a

robot to help encourage a child like them to play. Throughout the session, the research will ask you and your child questions to learn about your thoughts on robots for play and clarification your design decisions. We will audio record the session starting with the demo until the end of the creation period and the following questions. **Participation in this study is voluntary: you may choose to withdraw from this study at any point, and you will still receive your honorarium.**

Risks and Discomforts
There is also a potential physical risk because of the robots that will be involved but we will have a perimeter around the robot to help avoid physical contact with the robots. There is a small attachment risk in the demo portion with our robot. Attachment risk just means that people can become attached or bonded to the robots and may be upset or sad that they cannot keep them. Other than this, the risks to this study are no greater than in everyday life.

Benefits
Direct benefits are to experience cutting edge commercially available that many people do not commonly get to see or interact with. The indirect benefits will be having an opportunity to contribute to research that will influence the creation of technology designed to help other children with similar disabilities or special needs.

Honorarium:
In appreciation for your time and participation in this study, you will be compensated $20 cash for your session which will be given to you at the start of the session. If you withdraw during the session, you will still receive the honorarium.

Confidentiality
Information gathered in this research study may be published or presented in public forums, however your name and other identifying information will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed as our study will be with your family unit. We will ask everyone in your family unit to respect each other's privacy but cannot guarantee they will keep everything from the session confidential. Your personal information may be disclosed if required by law.

All information you provide is considered completely confidential; your name will not be included, or in any other way associated, with the data collected in the study. Audio recordings and photos of the materials/creations generated during the session are essential to the research analysis. Data collected during this study will be used for data analysis purposes only. Audio recordings will be transcribed either by our research team or a professional transcription service. If we use a professional service, the file will be renamed and not associated with you. We may use anonymized quotes from your session for purposes of public presentation; however, we will not present the audio. Each participant will be assigned a participant ID that will be used to present anonymized quotes (e.g., P4 for participant 4). That is, your voice and name will not be used in papers, presentations, put on the internet, etc. Please initial your response below.

- I CONSENT to be voice recorded and am aware my audio will be captured. _______

All the digital data will be stored in the University of Manitoba Microsoft server, OneDrive.

To which only researchers associated with this study have access until October 2025. After October 2025, the data will be destroyed. Once published (in journals, conferences, University of Manitoba MSPACE repository or thesis of students), results of the study will be made available to the public for free at hci.cs.umanitoba.ca by June 2024. Again, no personal information about your involvement will be included. Please note that the University of Manitoba may look at the research records to see that the research is being done in a safe and proper way.

Voluntary Participation/Withdrawal from the Study
Your decision to take part in this study is voluntary. **You may refuse to participate, or you may withdraw from the study at any time, and you will still receive the honorarium**. Your decision not to participate or to withdraw from the study will not affect your care at this centre. You can withdraw during the study by letting any of the research staff know or email the researchers following the study within 2 weeks of your session. If you withdraw in the middle of the session, we will immediately stop the session for you and your accompanying family unit. When you withdraw, we will remove all data from our study pertaining to you or anyone in your family unit. If the study staff feel that it is in your best interest to withdraw you from the study, they will withdraw you without your consent.

Study Results
You have the option to be contacted with the results or any publications that result from the study you participated in. If you would like to be contacted with the results list your email below and initial your consent. The results are anticipated to be ready by June 2024.

- I would like to receive the results from the study and CONSENT for me to be emailed at ______________________________ with them. Initial: ________

Safety
If any information you give reveals a current danger to yourself or another person, or of a child that is possibly in danger of abuse or neglect, the researcher will be required to share this information with other individuals. This may include child protection authorities, police, professional regulatory bodies or offices responsible for the investigation of vulnerable adults. Information would only be reported to police in cases of a risk of harm to either yourself or another identifiable person. In the case of information involving a child being harmed or at risk of being harmed, the researcher will report the information upon which the concern is based and any identifiable information they have to the local child welfare authority.

Questions
You are free to ask any questions that you may have about the study and your rights as a research participant. If you have any concerns or complaints, you may contact Dr. James E. Young at young@cs.umanitoba.ca, or the Human Ethics Secretarial at 204-474-7122 or humanethics@umanitoba.ca. This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. A copy of this consent form has been given to you to keep for your records and reference.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Raquel Thiessen and or her study staff. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor, or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential. I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

Participants signature________________________ **Date _______________**
(day/month/year)
Participants printed name: ______________________

Researcher's signature________________________ **Date _______________**
(day/month/year)

Appendix B: Child Consent Form

Project Title: Re-thinking Social Robots for Children with Disabilities: Learning from Family Units
Primary Researchers: Raquel Thiessen (Masters Student), Dr. James E. Young (Professor), Dr. Jacquie Ripat (Associate Professor)
Research Emails: thiess83@myumanitoba.ca, young@cs.umanitoba.ca, Jacquie.Ripat@umanitoba.ca
Researchers in Attendance: Raquel Thiessen (Masters Student), James Berzuk (Research Assistant), Nathan Lo (Research Assistant)

Your child is being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with others before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Study Purpose:
Your child is invited to participate in a research study on the topic of collaboratively working with children with disabilities or special needs and their families on designing social robots.

This study will take place at SSCY where your child will meet some real robots and then work collaboratively with you on designing a robot they would want to play with. The goal of this study is to learn what children with disabilities would need and look for in a social robot for play. Your child's participation in this research study involves drawing or building a robot model and creating some stories about how they would use their robot. If you have any questions or concerns, please feel free to contact the researchers at the above email addresses.

Study Procedure:
Your child's participation in this study will take approximately 60-75 minutes. Before participating in the session, you have to sign this consent form on behalf of your child. After starting the session, the researcher will give your child an overview of what they will be doing and ask for their assent. We will start with a brief demo with real robots and then we will go through a creation process to have your child design a robot to help encourage a child like them to play. Throughout the session, the research will ask you and your child questions to learn about your thoughts on robots for play and clarification your design decisions. We will audio record the session starting with the demo until the end of the creation period and the following questions. **Participation in this study is voluntary: you may choose to withdraw from this study at any point, and you will still receive your honorarium.**

Risks and Discomforts
There is also a potential physical risk because of the robots that will be involved but we will have a perimeter around the robot to help avoid physical contact with the robots. There is a small attachment risk in the demo portion with our robot. Attachment risk just means that people can become attached or bonded to the robots and may be upset or sad that they cannot keep them. Other than this, the risks to this study are no greater than in everyday life.

Benefits
Direct benefits are to experience cutting edge commercially available that many people do not commonly get to see or interact with. The indirect benefits will be having an opportunity to contribute to research that will influence the creation of technology designed to help other children with similar disabilities or special needs.

Honorarium
In appreciation for your child's time and participation in this study, your child will be compensated with their choice of toy or $10 CAD for the session. We will let them choose their compensation once the session is over. If they withdraw during the session, they will still receive the honorarium.

Confidentiality
Information gathered in this research study may be published or presented in public forums, however their name will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed as our study will be with your family unit. We will ask everyone in your family unit to respect each other's privacy but cannot guarantee they will keep everything from the session confidential. Your personal information may be disclosed if required by law.

All information you provide is considered completely confidential; your name will not be included, or in any other way associated, with the data collected in the study. Audio recordings and photos of the materials/creations generated during the session are essential to the research analysis. Data collected during this study will be used for data analysis purposes only. Audio recordings will be transcribed either by our research team or a professional transcription service. If we use a professional service, the file will be renamed and not associated with you. We may use anonymized quotes from your session for purposes of public presentation; however, we will not present the audio. Each child participant will be assigned a participant ID that will be used to present anonymized quotes (e.g., C4 for child participant 4) and we may include the child's age or other disclosed descriptors to provide context to their quotes (e.g., C4 aged 6 with cerebral palsy). That is, your voice and name will not be used in papers, presentations, put on the internet, etc. Please initial your response below.

- I CONSENT for my child to be voice recorded and am aware their audio will be captured. Initial: _______

All the digital data will be stored in the University of Manitoba Microsoft server, OneDrive. To which only researchers associated with this study have access until October 2025. After October 2025, the data will be destroyed. Once published (in journals, conferences, University of Manitoba MSPACE or thesis of students), results of the study will be made available to the public for free at hci.cs.umanitoba.ca by June 2024. Again, no personal information about your involvement will be included. Please note that the University of Manitoba may look at the research records to see that the research is being done in a safe and proper way.

Voluntary Participation/Withdrawal from the Study

Your decision to take part in this study is voluntary. **You may refuse to participate, or you may withdraw from the study at any time, and your child will still receive the honorarium.** Your decision not to participate or to withdraw from the study will not affect your care at this centre. You can withdraw during the study by letting the research staff know or email the researchers following the study within 2 weeks of your session. If your child withdraws in the middle of the session, we will immediately stop the session for them and their accompanying family unit. When they withdraw, we will remove all data from our study pertaining to anyone in their family unit. If the study staff feel that it is in their best interest to withdraw them from the study, they will withdraw the family without your consent.

Study Results

You have the option to be contacted with the results or any publications that result from the study you participated in. If you would like to be contacted with the results, please fill your email, and initial in the study results section on the guardian consent form. The results are anticipated to be ready by June 2024.

Safety

If any information you give reveals a current danger to yourself or another person, or of a child that is possibly in danger of abuse or neglect, the researcher will be required to share this information with other individuals. This may include child protection authorities, police, professional regulatory bodies or offices responsible for the investigation of vulnerable adults. Information would only be reported to police in cases of a risk of harm to either yourself or another identifiable person. In the case of information involving a child being harmed or at risk of being harmed, the researcher will report the information upon which the concern is based and any identifiable information they have to the local child welfare authority.

Questions
You are free to ask any questions that you may have about the study and your rights as a research participant. If you have any concerns or complaints, you may contact Dr. James E. Young at young@cs.umanitoba.ca, or the Human Ethics Secretarial at 204-474-7122 or humanethics@umanitoba.ca. This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. A copy of this consent form has been given to you to keep for your records and reference.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all your questions.

Statement of Consent
I have read this consent form. I have had the opportunity to discuss this research study with Raquel Thiessen and or her study staff. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor, or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential. I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

Guardian's signature________________________ **Date _______________**

(day/month/year)
Guardian's printed name: ______________________

Child's signature _____________________________ **Date ________________**

(day/month/year)
Child's printed name: ____________________________

Researcher's signature________________________ **Date _______________**
(day/month/year)

Appendix C: Demographic Questionnaire

Project Title: Re-thinking Social Robots for Children with Disabilities: Learning from Family Units
Researchers: Raquel Thiessen, Dr. James E. Young, Dr. Jacquie Ripat (thiess83@myumanitoba.ca, young@cs.umanitoba.ca, Jacquie.Ripat@umanitoba.ca)

Participant ID: ____

1. **What is your child's gender?**

   ☐ Male ☐ Female ☐ Non-Binary ☐ Other

2. **What age is your child?**

   ____

3. **How many other children live in the same household as this child?**

   ☐ 1 2 ☐ 3 ☐ 4+ ☐

4. **Is there anything you would like to disclose about your child's disability?**

   ____

   ____

   ____

   ____

Appendix D: Recruitment Email Template

Subject: Invitation to participate in a Support Robot Design Research Study with Your Child

Hello! We are running a study where we talk with families that include children with physical disabilities, to better learn about how to design support robots for people's daily lives. We invite you and your child to participate in a simple workshop at SSCY (Specialized Services for Children and Youth) where we will introduce you both to several robots, and we will ask you to collaboratively design a robot they would want to play with (e.g., through drawing a robot, building one from pieces, and creating a story). The goal of this study is to learn what children with disabilities would need and look for in a robot for play, as well as to understand family concerns and desires. The study is highly flexible, and children of all ability levels are welcome. Other family members (e.g., siblings) are also welcomed to join.

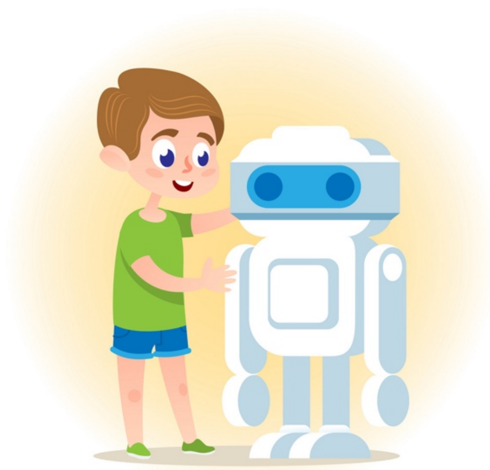
Participation in this study will take approximately 60-75 minutes. Throughout the session, the researcher will discuss with you and your child about your thoughts on robots for play and clarification of your design decisions. In appreciation for your time and participation in this study, your child(ren) will each be compensated with their choice of toy for the session or $10 CAD, and you will be compensated with $20 CAD. Participants will contribute to research about designing robots to support children with physical disabilities to play, which could lead to the development of new technologies built for these children.

To participate in the study, a guardian must be present with their child during the entire session. Further, at least one participating child must live with a physical disability. We are recruiting children aged 4-14; siblings of other age ranges are welcome to join but we will not collect data from their participation. To be eligible you must consent to being audio recorded for the session. **If you are interested or need more information, please contact Raquel.**

Principal Investigator: Dr. James E. Young
Co-Principal Investigators: **Raquel Thiessen (thiess83@mymanitoba.ca),** Dr. Jacquie Ripat
Research Assistants: James Berzuk, Nathan Lo

Appendix E: Recruitment Poster

Are you interested in meeting some robots and contributing to the design of future support robots?



We are looking for people to participate in a 60 –75-minute session to learn what children with physical disabilities would need and look for in a social robot for play. This study will take place at SSCY (Specialized Services for Children and Youth) where you and your child will get the opportunity to meet some real robots and then work collaboratively on designing a robot they would want to play with. The study is highly flexible, and children of all ability levels are welcome. Other family members (e.g., siblings) are also welcomed to join.

You and your child's participation in this research study involves drawing or building a robot design and creating some stories about how they would use their robot. In appreciation of your time, you will receive $20 (Canadian dollars) in compensation and your child(ren) will be given the opportunity to choose a toy or $10 (Canadian dollars) of their choice after the study. Participants will contribute to research about designing robots to support children with physical disabilities to play, which could lead to the development of new technologies built for these children.

We will follow all necessary university-mandated protocols and SSCY's protocols for COVID-19. To qualify for the study, you will need to participate with your child, you must consent to be audio recorded for the session and your child must be between 4-14 years old. If you are interested to be a part of the study, please contact the researcher at the below email.

Principal Investigator: Dr. James E. Young
Co-Principal Investigators: Raquel Thiessen (thiess83@mymanitoba.ca), Dr. Jacquie Ripat
Research Assistants: James Berzuk, Nathan Lo

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Gary campus. The Research Ethics Board can be reached by phone (204) 474-6791 or email humanethics@umanitoba.ca.

Appendix F: Sample Study Script

Sample Study Script & Procedures

Appendix F – Sample Study Script & Procedures
Project Title: Re-thinking Social Robots for Children with Disabilities: Learning from Family Units
Researchers: Raquel Thiessen, Dr. James E. Young, Dr. Jacquie Ripat (thiess83@myumanitoba.ca, young@cs.umanitoba.ca, Jacquie.Ripat@umanitoba.ca)

In this document, all text in blue refers to text spoken by the researcher. Black text is explanation and exposition.

Consent section

Consent procedure – 10 minutes

Part I: pre-study introduction - [1-2 minutes]

SCRIPT

Hello! I am Raquel, I am a master's student at the University of Manitoba. I will be running the study today. In this research study we will be working with families such as yourself to help understand how we can design and build robots for children with *physical disabilities and special needs*, to encourage them to play. We want to use these robots to help encourage children to play to help with their development and for them to have fun! These robots could be something they use at home, at school or at a clinic such as SSCY (Specialized Services for Children and Youth).

We have some robots with us here *[reveal robots (they will start hidden)]*. For your safety we will ask you to stay behind this box *[point to taped area around the robots]* and not touch the robots unless we say it is okay. Some robots look like people, such as this one *[point to Nao]* or animal-like such as that one *[point to Aibo],* and they act like people or animals to make them easier to work with. Research has shown these robots can support kids, for example, to play with other children, or to help them engage with therapy and activities. We're investigating new robots to try and increase child motivation and engagement and development towards their communication, mobility, and social skills. They also get to have fun with robots!

In this study we will start by showing you some of our robots, and I will then ask you some questions about what you thought about them. We then will ask your child(ren) to draw or build a robot that they may like to play with – you can help them or join if that's best – or they can design with the focus of creating a robot to help encourage other children with physical disabilities to play. Then, we will come up with scenarios or stories on how you imagine the robot could be used. Our session today will be audio recorded for analysis later.

We ask that you keep your interactions during our session private and respect the privacy of the other family members in the group. There is a small attachment risk during this study to the robots in the demo. Attachment risk just means that people can become attached or bonded to the robots and may be upset or sad that they cannot keep them.

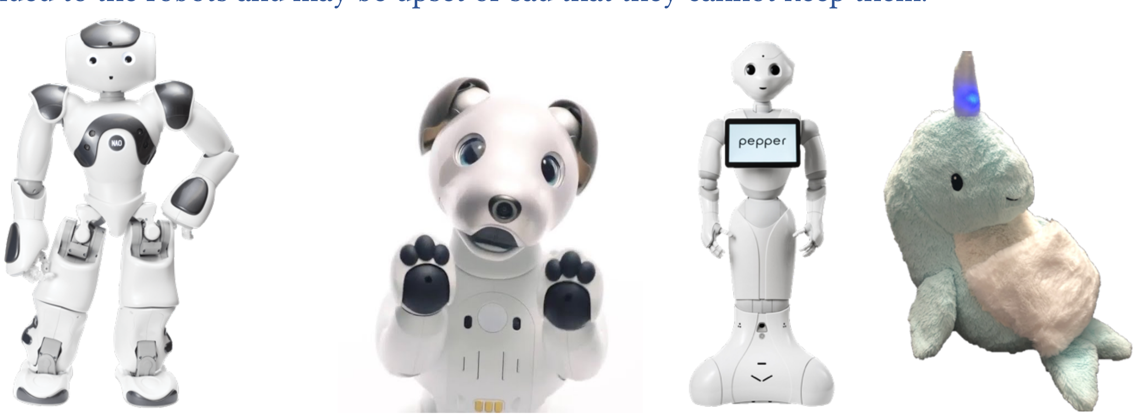


Figure 3. Nao (first), Aibo (second), Pepper (third), SnuggleBot (fourth)

Part ii: consent form - [5-6 minutes]

SCRIPT

Here are the consent forms for yourself *[hand them the consent form],* and this is the consent forms for your child(ren) *[hand them the consent form].* Please take some time reading the consent forms carefully before signing. The child's form is almost the same as the adults. I have highlighted the changes so you can quickly see what is different. We have two copies of each, one for our records and one for you. Once you have carefully read the form, please sign, and date both your child's and your consent form, both copies. Feel free to ask me any questions at any time. While you read this, I will ask your child for their assent as well.

After you sign the consent form, I will give your honorarium. I will also give the child a toy of their choice or $10, but we would like to give that as you leave to avoid any possible distractions. In all cases, you get to keep your honorarium and the child(ren) still get theirs, even if you stop participating at any time.

Part iii: assent - [2-3 minutes]

SCRIPT

As I mentioned earlier, we will start by showing you some of our robots and asking you some questions about them. You will then draw or build a robot that you would like to play with – they *[indicate guardian]* may help you if you like. You can also think about a robot to help other children with physical disabilities to play. We will then ask you to come up with scenarios or stories on how you will play with the robot.

I will record you speaking and take photos of your creations. You will not be in any of the photos. At any time, you can ask questions if you do not understand something. If you have questions later, you can ask me at any time. If you are not comfortable or do not want to do something, that's okay - you don't have to.

You are free to stop at any time, or not answer any questions, or do anything you don't want to do. Ask me any time if you are confused about anything or have any questions. Would you like to try this out? Do you have any questions?

Note: for nonverbal children, rely on guardian assessment of assent

Study procedure

Phase a) exposure to robots – 10 minutes

Part I: exposure introduction - [1 minute]

SCRIPT

In this study we are working with families such as yourselves to better understand how we can design and build robots for children with physical disabilities or special needs, specifically to support them to play. During this phase, I will demonstrate these robots and then ask you a few questions about your thoughts on how robots may fit into your home and family. For your safety we will ask you to stay behind this box *[point to taped area around the robots]* and not touch the robots unless we say it is okay.

Part ii: exposure demonstration - [5-7 minutes]

SCRIPT

Now I will show you some of our robots and a little bit of what they can do.

The first robot we have here is the Nao robot.

> Nao: Hello!
>
> Researcher: Hi!
>
> Nao: I see we have some new friends today! What are your names?
>
> Family Unit: *[says names]*
>
> Nao: Nice to meet you, my name is Nao! *[wave]*
>
> Researcher: Nao can stand up, walk around and do tai chi! Let's show them.
>
> Nao: Sure! Let me stand up first *[Nao stands up]*. I'm ready!
>
> Researcher: *[grabs Noa's hand]*
>
> Nao: *[Nao takes a few steps]* Yay I did it! Now ill do Tai Chi! *[Nao does Tai Chi]*
>
> Researcher: Thank you Nao!
>
> Nao: You're welcome. *[sits down]*
>
> Researcher: Bye Nao!

Our second robot here is Aibo [*Aibo just being on walking around*]. Aibo is a dog robot who you can teach tricks and pet and it will just wander around and bark sort of like a real dog! Though as you can see, Aibo just wanders without much sense of direction and cannot be walked like a real dog.

Our third robot here is Pepper. Pepper acts very similar Nao but just is a lot bigger!

> Researcher: Hello Pepper!
>
> Pepper: Hello!
>
> Researcher: Could you introduce yourself to our guests?
>
> Pepper: Hi! I am Pepper! I am the older sibling to Nao. We can do a lot of similar things, though I have wheels instead of legs!
>
> Researcher: Thank you Pepper!

Lastly, we have robots like SnuggleBot, that's made to cuddle with. Would you like to hold it? [if yes, carefully give the child SnuggleBot to hold or guardian if the child does not want to]. SnuggleBot was built by another student to help keep people company and give them a cute and cuddly companion. [take back SnuggleBot, if time allows, they can hold it for longer]

Phase B) Elicitation – 40-50 minutes

Part I: reflection [10 minutes]

SCRIPT

I'd like to now take some time to talk about the robots you just saw and what you liked or did not like about the robots and how you would imagine you or a child would want to play with them or have one in their home or school. So, let's begin!

INTERVIEW

During this activity we will take time to go through and ask them a few questions. We will conduct a semi-structured interview with the family unit to help them reflect on the robots they saw in the demonstration. Some questions will be more aimed toward guardians, some toward children or both.

Example Guiding Questions:

- What is your favourite robot?
- What did you like about *[favourite robot]?*
- What do you wish *[favourite robot]* could do?
- How do you think a child could play with these robots?
- Could you Imagine having one of these robots in your household?
- Are there any general concerns you would have with your child playing with these robots?

Part ii: creation [10-20 minutes]

SCRIPT

Next, we will create our own robot design! We have two options, you can do any that you like. You can draw your own robot, maybe draw some pictures of how you or another child may play with the robot. Or, I have this nice block kit where you can build your robot and show me how you imagine you or another child would play with it. Which would you like to do?

INTERVIEW

During the activity we will conduct a semi-structure, free-flowing interview, where we ask questions and prod on decisions and designs made. Depending on how the child & guardian perform the activities we will focus our questions on either the child or parent, or potentially both. The interviews will be therefore interspersed, some questions targeted at the guardian and some toward the child.

Example Parent Focal Points: **Robot Design Opinions**

- Would you feel comfortable having a robot like the one your child described at home/school?
    - What characteristics/abilities/precautions would you say the robot would need for you to feel comfortable having this robot in your home/ at school?
- Are there any concerns you would have with a robot such as this playing with your child(ren)?
- Are there any important abilities you feel the robot should have?
- How do you imagine your child would use this type of robot?
- What important aspects would you say the robot would need for you to feel comfortable having this robot in your home?

Example Child Focal Points: Robot Design Decisions

- Would you want a human looking robot, animal like or more machine like?
- Why does it have legs? Why does it have wheels?
- Would your robot be big like pepper or small like Nao?
- What would you want your robot to be made of?
- Where do you imagine children could use this robot?
- Why did you design it with X attribute?
- What do you think it should be able to do?

Activity Option 1: DRAWING – 20 minutes

SCRIPT

Could you please draw a robot that you would like to play with or would like to make for other children to play with? You can make as many robots as you like, or just one, it's up to you. We have lots of different markers, crayons, and pencils. While you draw, I will ask you some questions about your robot.

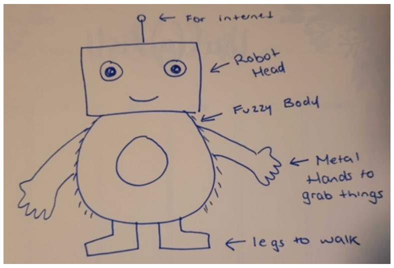
[to the guardian] If you would like you can work with your child(ren) collaboratively, supervise or even make your own design that you your children would want to play with and could benefit from.

I'll give you some time to do this and then I will ask you to tell me about your design. Feel free to ask me any questions or let me know if you get stuck and want some help.

MATERIALS

Big Paper, Markers, Crayons, Pencil Crayons

Example:



Activity Option 2: BUILDING – 20 minutes

SCRIPT

Could you please build a robot that you would like to play with or would like to make for other children to play with? You can make as many robots as you like, or just one, it's up to you. We have lots of different pieces in our robot building set here that you can choose from to build your robot. During or following your creation, I will ask you some questions about your robot.

[to the guardian] If you would like you can work with your child(ren) collaboratively, supervise or even make your own design that you your children would want to play with and could benefit from.

I'll give you some time to do this and then I will ask you to tell me about your design. Feel free to ask me any questions or let me know if you get stuck and want some help.

MATERIALS

3D printed pieces (Velcro tape to connect them), clay, googly eyes, other craft materials
Example:

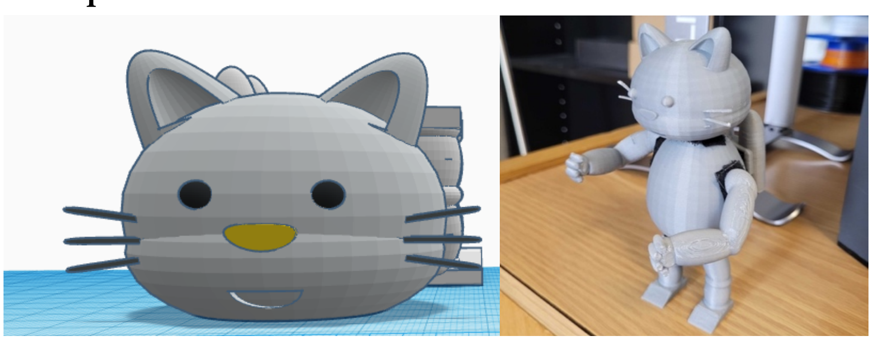


Figure 4. Cat Model (left), 3D Printed Model (right)

PART III: SCENARIOS / STORYTELLING [10-15 MINUTES]

SCRIPT

Note: Depending how the flow of the session goes this portion of the script may not be spoken. If the child(ren) and guardian naturally transition into talking about scenarios and uses for their robot designs, we would go with it more organically. If not, then we will try to make a break in their activity and shift towards this.

In this activity, you will work together to tell a story of your robot that you designed for yourself or another child with physical disabilities to play with. The scenarios/stories can include activities they would do with it, where they would bring it, collaborative uses for it, etc. You have the option of drawing the story, acting it out with your model, just talking to me or a combination. I'll be here the whole time so if you want to just tell me them, we can do that now and I can ask you some questions about it or you can work on it and present your story at the end. Feel free to ask me any questions or let me know if you get stuck and want some help.

MATERIALS

Big paper with story boards, maybe some blank paper as well, other props they could use to make their story
Example:

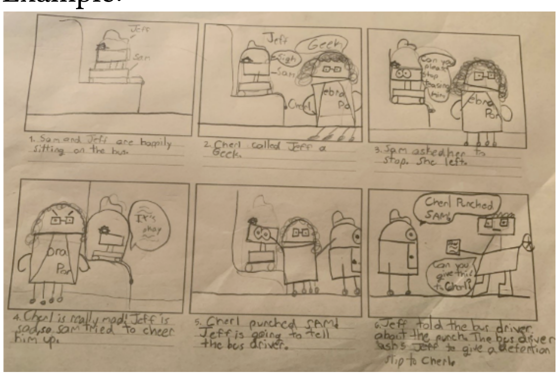


Figure 5. Storyboard Example

INTERVIEW

During the activity we will conduct a semi-structure, free-flowing interview, where we ask questions and prod on decisions and designs made. Depending on how the child & guardian perform the activities we will focus our questions on either the child or parent, or potentially both. The interviews will be therefore interspersed, some questions targeted at the guardian and some toward the child.

Parent Focal Points: **Interactions with the Robot**

- What role do you feel the robot could play in an interaction with your child? ex. Motivator, Companion, Toy
- Is there anything that might make it hard for your child to play with the robot?
- Are there any concerns you would have with your child interacting with such a robot?
- Are there any concerns you would have with incorporating activities with the robot in your child's home routine?

Child Focal Points: Activities with the Robot

- Where is your story taking place?
- Would only you play with the robot or others too?
- How are you playing with the robot?
- What activities can you do with the robot?
- Is there anything that might make it hard for you to play with the robot?
- Is there anything that might make it hard for the robot to play with you?
- Would you say your robot acts like X? (Pet, friend, sibling, teacher)

CONCLUSION – 2 minutes

SCRIPT

That is all our time for today, thank you for participating in our study! Since you did such a good job participating in our study, would you like $10 or pick a toy to take home! *[give kids the options]*. If you want, you can take the drawing/prototype and storyboard you made home with you.

Do you have any other questions before we leave today?

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