Understanding Family Needs: Informing Social Robot Design to Support Children with Disabilities to Engage in Play

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Abstract

While children with disabilities often face barriers to play including reduced time, exclusion, and ill-suited toys, impacting their development, social robots provide the potential to help: they can motivate children, increase task engagement, and facilitate social interactions. However, social robots (and technological interventions in general) struggle to be adopted into regular use within homes by families, commonly being abandoned after a short time. Rather than focusing on the utility of these interventions, we instead look how they integrate into family needs and lifestyles. We designed and conducted a study where we engaged children living with disabilities and their families, using interactions with real robots and exploratory exercises, to learn about their perspectives, needs, and concerns regarding adopting a social companion robot in their home. We analyzed participant task engagement and feedback from the perspective of supporting play for children with disabilities and presented resulting design recommendations for addressing primary concerns and matching key expectations, and to support adoption pathways to improve the chances of success.

CCS Concepts

• **Human-centered computing**; • **Accessibility**; • **Empirical studies in accessibility**;

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1 Introduction

For children, play is a crucial aspect of their development and a fundamental human right [3, 32]: through play children develop their physical, emotional, social, language, cognitive abilities, and creativity [4, 15]. However, in recent years, time for children to play has decreased compared to the past [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 [6, 55]; as a result, they may experience isolation from their peers [56]. Insufficient play opportunities can also lead to peripheral impacts, such as children erroneously believing they are incapable of performing tasks despite having the ability to do so (i.e., "learned helplessness" [19]). As such, research continues to explore interventions and supports to assist children with disabilities in engaging in play.

Interventions to enhance children's play participation include designing play environments [63], working on children's play skills [36], or leveraging technology to facilitate or motivate play [24]. Early research on robots supporting play for children with disabilities is promising, including a range of robotic tools (e.g., PlayROB [39] and myJay [41]) that can compensate for a child's physical

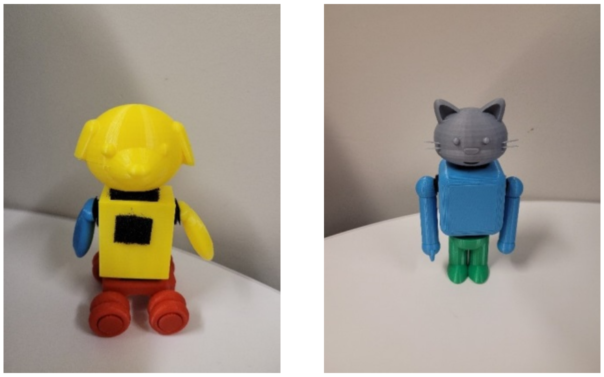

Figure 1: We engaged children with disabilities and their families in participatory design exercises to facilitate holistic reflection on desires and concerns about adopting a social robot into their lives.

or cognitive skills during play [39, 41], potentially increasing the child's playfulness and aiding in cognitive and motor development [51]. Additionally, social robots that use human or animal-like social behaviors [11] and a physical presence [60] use richer communication to create an even more engaging interaction experience [65]; these can encourage children and facilitate social interactions and social play [33, 35, 45]. For example, research has leveraged social robots to motivate children with neurodevelopmental disorders [52, 61] to engage in their therapies [26] and foster interactions with peers [40].

Unfortunately, despite these potential benefits there remain challenges with robotic interventions being successfully used and adopted into homes for long-term use (e.g., [25, 26]). Current indications are that robots simply may not be designed for long-term engagement [16], may not meet users' expectations [28] or fit families' social and pragmatic needs and constraints [12, 29], or may not be well adapted for children's specific needs [26, 28]. This problem of social robot adoption has been identified as a key challenge of social robots in general [29]. To mitigate this, researchers are increasing stakeholder involvement, including children, throughout the design process to bring diverse perspectives, foster input and feedback, and mitigate researchers' assumptions and biases [18]. For example, using co-design techniques to engage children of all ages to help design robots for creativity [2], mental health [8], and education [43].

All of this points to the need for more engagement with children and their families, to better understand their needs, expectations, and constraints to inform the development of successful companion robots to support play. In this work, we conducted a study to engage children with disabilities, and their families, with real robots and design activities in order to learn about their high-level but nuanced needs, desires, and concerns relating to adopting a social companion robot for their child. We created an original study design that leveraged real robots and participatory design strategies to foster rich participant engagement and facilitate deep, meaningful reflection on adopting a robot. We recruited a total of 8 families, including 8 children (aged 3.5-11) living with disabilities, engaged them with exercises to consider practical robots in their daily lives, and conducted semi-structured interviews throughout the process. Our analysis of the results indicated that families were highly receptive to accepting a social robot, and importantly, outlined how families envisioned such robots may enter into their lives and what potential barriers may be. We summarize findings and present a set of design recommendations that provide robot creators with potential pathways toward designing social robots to support play that may mitigate common concerns, fit expectations, and ultimately may be accepted.

Social robots provide a unique opportunity to support children with disabilities to play, and the community needs to learn more about how these children – and their families – envision such robots will enter their homes and daily lives if we are to build successful robot interventions. On this front, our work provides an original and unique perspective from children and their families and provides the community with some of the first concrete high-level recommendations for designing social companion robots for play to be adopted and used by children in their homes.

2 Background and Related Work

Researchers have established multiple ways that social robots can be used with children, such as motivating and engaging children to play or participate in developmental activities [7], [8], establishing positive relationships [17], or improving children's social behavior [10]. Further, a range of research has demonstrated the use of social robots for targeted applications such as rehabilitation [34, 50], education [5], emotional support [42, 44], and play [26]. We follow these preliminary results, typically conducted in highly controlled or laboratory settings, by focusing on the nuanced real-life needs of families and children for adopting such robots, interventions, and interaction designs into their homes and daily lives.

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 [1]. 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.

Some research has explored key design characteristics relating to acceptance and adoption into homes, for example, user perceptions of a social robots' capabilities [22] and social intelligence, usability, practical benefits of adoption, and children's safety around the robot, may be important for influencing domestic acceptance and integration [66]. We extend this work by focusing on the specific needs and nuances relating to children with disabilities and their families, as well as the particular use cases for a robot for this group.

Few projects intersect social robots and children with disabilities. Previous research used a commercial robot platform called ZORA, built on a Softbank NAO H25 robot [26, 27], to engage children with disabilities in therapies, finding that it increased the child's concentration and attention. However, in this work, the researchers noted technical challenges with therapy professionals using the robot, including the lack of appropriate scenarios (as judged by the professionals) and the professional's inability to customize a session's scenario to match a child; that is, perhaps their design did not sufficiently consider users' needs and social structures.

Another example is the IROMEC robot, created in collaboration with healthcare professionals and engineers for children with physical disabilities and those with autism spectrum disorder (ASD) [13, 25, 28, 53]. This robot was developed to support children with disabilities in their play therapy and was able to positively impact outcomes toward their rehabilitation goals in the short deployment. A key result of this work is the identification of potential use and adoption barriers: for example, the larger size of the robot was impractical for small children or those in wheelchairs, and the robot demanded specific cognitive and motor abilities (e.g., pressing the buttons on the robot) that not all children possessed, sometimes exceeding the capabilities of children [28]. Furthermore, some professionals in this work noted that robot malfunctions lead to children being disappointed, highlighting the importance of robots functioning as expected and that the number of sessions with the robot was insufficient for some children to acclimate to it. As such, our work attempts to engage with the root of these broad issues by taking a step back and engaging children and their families to learn about their practical and social needs, expectations, and fears regarding adopting a robot, to increase the chances of such robots being widely adopted.

The existing background work highlights the potential for social robots to support children with disabilities to engage in play but also emphasizes the general lack of existing solutions that have been able to successfully integrate into homes. Our research aims to contribute to this growing field by engaging these families directly, by involving them in a study designed to help them consider deeply adopting a companion robot into their homes, and enabling us to focus on their nuanced expectations, needs, and concerns.

2.1 BACKGROUND: PLAY

"Play" is a complex concept with various components depending on the context and the child's developmental stage; as such there are many definitions of play across fields of study (e.g., see Stagnitti [57], for a survey); for our purposes we follow Garvey [14] and define play as an enjoyable, voluntary, intrinsically motivated activity. In the remainder of this section, we outline the dimensions of play and the stages of play children go through as they develop; overall this understanding of play informs our study design and the data analysis.

These are two broad dimensions of play: cognitive (practice, symbolic, constructive, and play with rules) and social (solitary, parallel, associative, and cooperative) [7]. The cognitive dimension of play refers to the intellectual and mental aspects of play activities that promote learning, problem-solving, and cognitive development [49]. The social dimension of play refers to how play activities and interactions contribute to social development and relationships such as fostering communication, empathy, and cooperation skills [46]. Balancing both dimensions and their respective types of play is crucial for children's overall development, promoting cognitive, emotional, and physical growth, and ensuring diverse play opportunities in diverse settings helps children develop a well-rounded skill set.

Within these dimensions, Piaget [49] proposed that children progress through a series of stages of play during cognitive development, starting with "sensory-motor play," which encompasses activities that simultaneously engage a child's senses and motor control, including senses such as vision, hearing, and touch, as well as motor abilities like walking, talking, and running. For example, sensory-motor play activities include tummy time for infants, or throwing a frisbee for older children. Following this, Piaget [49] proposes "symbolic play," 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. Lastly, "complex pretend play," generally a more intricate form of pretend play, often involves activities like role-playing, where children take on different roles and act out scenarios.

These categories of play help frame the contexts within which families may envision utilizing the robot, and help emphasize the importance of considering a child's developmental phase with respect to play; this can further highlight where future play-support therapies may target to align with the child's development. We leverage this play background in our study design and analysis, focusing on elements which support the various types and elements of play.

3 Study

We designed and conducted a study with the goal of learning from children with disabilities and their families, to build a grounded understanding of the social and domestic environment that a social robot would need to integrate into. We designed our study to encourage participant engagement in considering a robot in their lives and to avoid potential superficial reflections or initial opinions without careful thought, by involving actual robots that ground reflection in the reality of current robots, and activities that involve imagining a robot in one's life. We drew heavily from participatory design [37] and co-design [9, 67] approaches, inspired by a previous project that successfully engaged children and parents for a pain management robot [68], using a series of props and activities to facilitate reflection and engagement in the task. We leverage tools from these domains to engage participants to support reflection, and as we are not designing a robot, we do not do co-design per se. Our research questions were as follows.

> R1. What are the concerns and perceived barriers of children with disabilities and their families to adopting a social robot for play?
>
> R2. What are the desires and perceived opportunities seen by children with disabilities and their families for a social robot to support play?
>
> R3. What ideas do children with disabilities and their families have about the roles and the social dynamic of the robot with the child?

Rather than aiming to design a specific social robot or interaction, our research goals are to more broadly gather insights about the critical factors pivotal for the more general effective integration for social robots, and tap into families' preferences and desires that can facilitate initial engagement. Our first research question does this by delving into the barriers they perceive, whilst the second and third unveil their desires, enabling us to use them as a gateway for adoption. Note that given this focus on the family unit and social adoption needs, we do not limit the study to particular age groups, disabilities, or family formats, to increase the generalizability of our results to a wide range of families.

3.1 Tasks

We designed a set of tasks to engage users in reflection and brainstorming regarding social robots to support play for children with disabilities, focusing explicitly on the range and forms of play outlined in Section 2.1.

Stakeholder Exposure to Robots. We demonstrate a series of actual robots (in contrast to, e.g., videos or images) to facilitate engagement and help ground participant ideas within what is technically feasible and pragmatic with current robotics technology. This helps counteract problems of inflated expectations regarding robots possessing human-like intelligence and physical capabilities of robots, driven by depictions in popular media [29]. We provided an approximately 10-minute interactive demonstration showcasing a series of robots and their capabilities and opportunities for participant questions and discussion about the robots. The demonstration featured robots engaging in conversation and using gestures to highlight potential for social play, such as parallel, associative, and cooperative play. Similarly, demonstrating the robots' physical abilities highlighted the potential to participate in physical play activities, covering a range of cognitive dimensions of play from practice play (e.g., throwing a ball) to play with rules (e.g., soccer). We took precautions to ensure child safety and restricted access to robots with pinch-point joints or could fall on them. Following the demonstration we conducted a verbal reflection elicitation exercise where we asked questions to family units designed to encourage them to consider how these robots may fit into their homes and lives. For example, we inquired about their preferences or dislikes concerning each robot, or if the guardian would be comfortable having any of these robots in their home, or any other concerns they might have.

Stakeholder Creative Exploration. We conducted a robot design exercise (inspired heavily by other co-design practices [9, 10, 62, 67]) which engaged children to acutely think about and envision what they would want in a robot; the exercise was a vehicle by which the whole family could reflect concretely on the potential for a robot to support them in their lives. Given the expected high variance in child ability and interest, we developed two robot design task options: for children to 1) build a new robot prototype from a building-block like toolkit (Figure 2, an example in Figure 1), or 2) draw a new robot design using a selection of drawing supplies. Following, we tasked children and their families to create stories using their robot design, by drawing it, acting out, or verbally describing it. If a child had trouble participating in this activity the researchers provided scenarios, for example, in one scenario we asked the children and their families to imagine their thoughts and feelings about the child's robot in a shared interest such as playing soccer. Throughout the entire task, we asked generally open-ended questions that were not tied to any specific form of play, to enable us to reflect on the potential of robots regardless of the dimension of

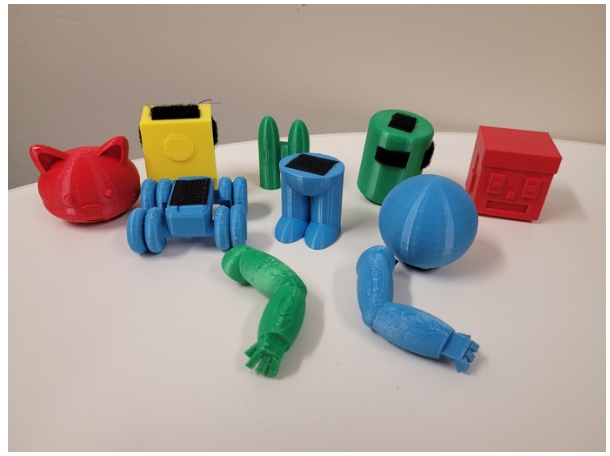

Figure 2: 3D printed build set created by the researchers. We provided a large number and range of colors of all the pieces shown.

play (i.e., cognitive or social) or child's development (e.g., sensory-motor, symbolic, or complex pretend play) targeted by the design. However, if toward the end of the activity there was something not discussed, we would then ask targeted questions to the family units about potential play or ways of interacting with the robot, drawing from our understanding of types of play (i.e., cognitive or social, sensory-motor, practice, symbolic, constructive, etc.). For example, thoughts on the social aspect of play, if they would play solitarily with the robot, in parallel with others, or collaboratively with other children or family members, etc.

3.2 Instruments

For the stakeholder exposure to robots task, we used a range of robots (Figure 3), including two different humanoid robots that engaged in short conversations with the researcher (Softbank Nao v6, 58 centimeters tall and 25 DOF, and Softbank Pepper, 1.2 meters tall and 20 DOF), with the smaller humanoid walking and dancing. We also introduced a pet dog robot, the Sony Aibo (29 cm tall), and a small cuddly companion robot called SnuggleBot (small pet-like narwhal robot), both briefly introduced and shown demonstrating their default pet or companion behaviors.

For the creative exploration phase, we designed an original toolkit inspired heavily by prior work (Robo2Box [47] and following studies [68]), to be quick and easy to use by young children with varying physical abilities, while still being flexible enough to support creativity. We modified resources from the Tinkercad [69] community designs to develop and 3D print our resulting pieces. The pieces were designed to be connectable using Velcro strips for ease of use for children with limited mobility. To support broad creativity we developed a wide range of robot design options (e.g., wheels, legs, wings, arms, paws, etc.) while attempting to avoid emphasizing any approach or morphology. For the drawing option, we provided a range of mediums including pencils, pencil crayons, felt markers, crayons, etc., to facilitate a range of children's abilities and interests.

Figure 3: Pepper [54], SnuggleBot [48], Aibo [29], and Nao [28]

3.3 Participants and Recruitment

We required children to be between the ages of 4 to 14, self-declared (by self or guardian) to have a disability, and have an accompanying guardian. In addition to our primary stakeholder group of children with disabilities, co-habituating guardians and other family members also have valuable knowledge on safety, privacy, home environment, and family dynamics. Therefore, we invited siblings and other family members to visit and participate. Given our goal of learning about home integration challenges for a play robot, and for broad input irrespective of disability and to mitigate recruitment challenges we decided not to target a specific category of disability. We also did not require families to disclose or provide verification of the disability, allowing us to prioritize inclusivity and privacy for our participants. Instead, we left it to the family's discretion if their child was eligible given our described eligibility. We were open to recruiting a diverse range of family units that included non-parental guardians.

We scheduled the families to participate in the study during visits for existing appointments to a local center called the Specialized Services for Children and Youth Center, a local center for children and youth to access medical care. This made it convenient for the families and allowed them to be in a familiar environment. Before the session, the guardian provided written informed consent for themselves and any children with them. The child participants and accompanying siblings gave verbal assent. All participants, including the children, accompanying guardians, and siblings, received honorariums for their participation. The guardian received $20 CAD, and the children were each given the option of $10 CAD or a toy from a pre-prepared selection.

3.4 Procedure

We conducted our study at the Specialized Services for Children and Youth Center, a local public healthcare clinic in Winnipeg, Canada, that provides services for children with disabilities and special needs. We first brought the family to a private room at the center to have a quieter and minimally disruptive environment for the study. Initially, we concealed the robots to minimize distractions while we outlined consent and assent procedures. We provided the option for families to disclose their child's disability in a demographics form but we did not require them to do so, nor did we require verification of their disability, given the sensitivity of the information and that our research did not target a specific disability. The study was performed in 1-1.5-hour sessions with only one family at a time.

Our research team consisted of a primary researcher, one research assistant to operate the robots, and one research assistant to assist with the session. The task of the first research assistant was to remotely control (wizard) the robots during the demonstration, enabling the primary researcher to concentrate on the session and ensuring consistency in the demonstration with each family. The second research assistant was an occupational therapy student who supported the primary researcher in engaging the child by adapting the methods and explanations extemporaneously according to the child's abilities and interactions.

After obtaining consent, we performed the stakeholder exposure to robots phase. This exercise also allowed the child and family member(s) to gain comfort in talking to the researcher. Following the demonstration, we did a reflection with the family on what they saw in the demonstration. We then moved on to the stakeholder creative exploration. The stakeholder creative exploration consisted of a creation, and storytelling task. We were flexible in our methodology to accommodate children with a range of abilities. For example, when working with non-verbal or communication-limited 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, perspectives, and explanations of their design decisions. The study session 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 had started to disengage. Upon completing the study, the child was given the option to keep their creation if they desired. Our procedure was reviewed and approved by both our institutions and the centre's research ethics boards.

3.5 Data Collection and Analysis

We recorded audio of our sessions and took photographs of all generated materials in the study activities; we did not videotape our

Table 1: Child Demographics

Child	Family Members	Child's Sex	Age	Disclosed Disability
C1	G1	male	5.5	ASD and ADHD
C2	G2	female	11	social and communication issues
C3	G3	female	3.5	issues walking and balancing
C4	G4	male	6	ASD
C5	G5, S5	female	11	intellectually disabled, apraxia of speech, issues walking
C6	G6	male	9	limited range of motion and unable to walk
C7	G7	female	5	paralysis of legs with minimal recovery
C8	G8	female	9	undisclosed

sessions due to privacy concerns regarding the child participants. In our qualitative analysis, we used a directed qualitative content analysis [30, 38]: one researcher developed an initial codebook based on our research questions and background literature regarding robots supporting children with disabilities, and then conducted an initial open-coding pass. Following, the primary researcher iteratively went through the data, eventually grouping our data into dominant themes and a set of recommendations. Additionally, we took photos of the participant's creative robot designs, although we only superficially analyzed them as their main function was to encourage participant engagement, foster discussions, and offer visual support for storytelling.

4 Results

Our recruitment resulted in 8 family units, with each unit consisting of one child (C#) and one guardian (G#) except for family unit 5 which included an accompanying sibling (S5), with a range of disclosed disabilities and ages (Table 1). We flexibly adapted our procedure to include the sibling, who in this case actively participated in the tasks throughout the study, assisting their sibling (living with a disability) as needed and directly sharing their thoughts with researchers.

Below, we highlight the prominent themes that emerged from our qualitative analysis of participant sessions, where we focused on understanding stakeholder perspectives on potential benefits, concerns, and the practical and social landscape of adopting a social robot for children with disabilities, to inform the design of social robots that will be adopted and accepted into homes. We highlight our key codes throughout the text.

4.1 Openness to Robots as Companions

Families demonstrated general openness to adopting a robot intervention to support play, for example, multiple family units (*G2, G4, G6*) described a **robot that would act as a companion**, giving the child "someone to talk to" (*G6*), play with and spend time with. Families readily envisioned a broad range of potential use cases or specific tasks for such a robot, such as one child who 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, multiple family units (5) described a **robot that would act like a pet** to play with (*CG1, CG4, CG6, CG7, CG8*), or take care of (*C6, C7*), with some guardians (*G4, G6*) reflecting on the potential for children who cannot have pets, to gain experience:

> *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*

Some families mentioned the potential for the **robot to provide emotional support**, both from guardians who felt a robot help children comfort them (G2, *G4*):

> *They should put them in schools because there are a lot of kids who are very sad and lonely – G2*

and children themselves:

> *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).*

Participants further discussed the potential for **robots to support children's existing interests and hobbies** such as reading to them (*G3, G4*), sports such as soccer (*C1, C2*), basketball (*C2*), volleyball (*C2*), and gymnastics (*C7*), or artistic activities such as singing (*C1, C6*), dancing (*C6, C7*), building (*G4*), and role-playing (*G4, C7*).

Moreover, some families (4) discussed the potential for using **social robots for pretend play**. In one case, the child (*C7*) shared her ideas about how the robot could join in her usual imaginative game of "princesses and dragons," including having a costume for the robot to get into character. Furthermore, throughout the session researchers noted that some of the children (*C1, C3, C5, C7*) actively engaged in pretend play using their robot creation throughout the session.

Guardians and children in most families (6) (*G1, G3-G6, G8*) stated that the child **would primarily prefer to play with their robot privately,** typically in their home, alone, or primarily with a family member (2 children). Two guardians provided potential explanations, such as the fact that this may simply reflect that their child currently primarily plays alone and does not have many friends:

> *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*

However, some (2) children expressed desire to share their robot with others, e.g.,

> *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*

Some guardians raised concerns about **social impact on children** and their interactions with others. One mentioned that having the robot at school or in public might cause their child to feel "protective of it and maybe overwhelmed" (*G4*), with another similarly noting how their child might struggle with other children playing with their robot as they have been on a 'mine' kick; this last guardian noted recent improvement with attachment and loss (*G5*).

4.2 Robots as Motivators for Therapy and Activities

Families often talked about the potential for social robots **to motivate children to engage in activities in general**, for example, providing encouragement:

> *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*

and to help get children outside or away from screens:

> *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*

Although one guardian noted a concern with getting their child to stop playing with the robot (*G7*).

A common theme was discussing how a robot could help with their child's general development, as a robot could patiently repeat and help a child with challenges such as supporting a child's communication development:

> *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 (C4 was non-verbal)*

Or specifics such as 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*

Others noted the potential for physical motor skills (G3-6)

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

Many guardians (*G2, G3, G5, G6, G8*) noted a potential for a social robot to motivate or help with more formal education, for example, 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*

> *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*

Or with their therapies, as a robot can serve as a source of motivation and could be patient:

> *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*

Or demonstrate and repeat physical actions:

> *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*

Some families (*2 guardians and 1 child*) talked about **service robots that provide disability-related assistance** beyond coaxing and supporting the child to do things directly. For example, one child who used a wheelchair talked about having a robot that could help them reach things that they would not be able to 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*

4.3 Disability-related Needs

Some participants raised needs particular to children living with disabilities. For example, some guardians noted that their children can be overstimulated, suggesting care for **robot acclimation** (*G3, G4, G5*) such as expecting time to adjust before fully engaging a robot:

> *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*

Further, researchers noted during the study demonstration task that some children were initially hesitant with the robots but gradually grew more comfortable over the course of the session 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.** For example, families felt that the robot should have a friendly appearance, with a soft voice and soft features (*S5, G3, G, 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*).

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 that their robot has emotions (*C2*).

Children themselves 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. For instance, one child (C7) only talked about the robot's safety until their guardian mentioned they would need to be careful to avoid the child tripping on the robot when she was using her walker. Even when prompted, their discussion about these considerations were minimal.

4.4 Safety Considerations

The most frequent concern and discussion point throughout the study was regarding safety in general. Some of this was regarding **safety of the child**, such as physical safety: four guardians (*G1, G5, G6, G8*) briefly expressed concerns such as their child's fingers getting caught in the robot (*G1*) or possibility of electric shocks (*G6*). Several families raised concerns over larger robots being intimidating, perhaps falling and causing harm (*G5*), or leading to children being timid (*G3*) or fearful (*C7*)

> *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*

In contrast, some expressed confidence in the safety based on our provided robot exposure, for example:

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

Under the umbrella of safety two guardians noted **comfort with AI**, for example, discomfort around concepts of technology being self-aware (G5), or lack of control:

> *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*

On the other hand, some guardians were more dismissive of such concerns: for example, "I'm not too fixated on iRobot" (*G1*) and "Well, sci-fi movies talk about robots taking over but that's all silly" (*G3*). No participant raised issues relating to privacy or security in their homes.

In contrast to above, there were a broader range and depth of concerns raised about the **safety of the robot** itself (*5 guardians, 1 child*) (*G3, G4, G5, G7, G8, C7),* for example, being damaged by the children. Guardians raised this concern on their own when asked generically about safety, despite the researchers not intentionally asking about safety of the robot, for example:

> *Researcher: 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*
>
> *Researcher: 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*

One guardian mentioned that their child can be destructive, and they were worried the robot being mistreated (*G7*), while another noted the potential high cost as a reason:

> *Researcher: 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*

Yet another noted the potential for losing the robot and the consequential emotional effects:

> *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*

When asked what would be important to consider for designing a robot for their children, guardians emphasized the durability (*G4, G7*). Researchers further observed guardians reminding their children (repeatedly) to be gentle and careful when interacting with the robots (*G3, G8*).

Finally, one child demonstrated concern 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*).

4.5 Environment and Space

Several participants talked about the **size of the robot in relation to their home**, for example, one guardian 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** for specific functionality or support, 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*). However, overall participants did not express many opinions or concerns about the integration of the robot into their physical spaces.

4.6 General Engagement

Throughout the study, participants were all engaged and participated in the tasks as expected, with children and families leveraging our flexible design based on abilities and family dynamics (e.g., guardian versus child speaking more). For example, there was a mix of children choosing building and drawing, and some children worked through and talked about their design more independently (*C2, C6, C7, C8*) while others engaged more collaboratively with their guardian and the researcher (*C1, C3, C4, C5*).

Further, we noticed that opinions and creations alike evolved as the study progressed, and participants had more time to engage in the tasks. For example, while children generally made designs that aligned with verbal descriptions (e.g., a child who described their robot like a dog robot incorporated the appropriate head in their design, *C6, C7*), but readily updated and modified their designs as they became inconsistent with their desires or description. For example, one child (*C7*) started with a robot with a leg component, but after describing their robot and how they would use it, changed for their robot to have wheels as they envisioned racing their robots (like one would in a wheelchair). Finally, 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 not mentioned originally.

5 Discussion

Our results indicate that our study successfully involved participants in engaged and careful reflection on a social robot to support children with disabilities to play, resulting in a rich set of key concerns, desires, and opportunities for robots to be adopted into homes. While participants often reflected on companion robots more generally, these results provide insights into how a robot for play may be received by families. More importantly, our results provide a range of opportunities and potential key factors that designers can look to when designing play-support robots and interventions for children with disabilities.

Overall, we found no signs of hesitation toward adopting a robot, and instead, our results indicate a high level of open-mindedness from families regarding how a robot may be adopted into homes and support children. Thus, this suggests that we may expect families to be receptive to novel social robots and interventions, at least initially. In fact, families readily provided an abundance of potential avenues for use cases for a social robot. This included companion-type roles (e.g., a pet) where some noted the potential for a child's growth (e.g., learning to care, etc.). In particular, children tended to express more interest in using the social robot for play and perceived the robot as a pet or companion.

However, it was more common for participants to discuss task-oriented pragmatic roles such as helping a child with homework, required activities, or even potentially supporting children with disability-related challenges and therapies. The prevalence of this in the discussion coincides with existing literature that emphasizes that children with disabilities often have more time prioritized for therapies, potentially leading to fewer opportunities for play [6, 55]. While these tasks are more utilitarian than play-related per se, the predominance of such use cases in the data highlights this as a potential indirect avenue for supporting social robot adoption. That is, perhaps a play-related social robot intervention could be packaged with, or piggybacked on, such utility-focused tasks to encourage buy-in and use by guardians.

Participant suggestions demonstrate openness and potential for a range of types of play supports that can shift as children age and advance along developmental stages. Suggestions around companion robots that could engage and motivate children, and help them with academic, communication, and development activities through their homework and therapies, could be useful for cognitive play. Further, many of the envisioned applications such as activities surrounding speech and motion could be leveraged for sensory-motor play that enhances sensory perception and motor skills. Ideas around robots that entertain or comfort children, for example mirroring a pet or a friend, could be leveraged to provide children with social play opportunities. This aligns well with participant discussions around children having predominantly solitary play with robots and the potential for a robot to help facilitate development to move toward play with other children (e.g., associative or cooperative). In fact, the participant focus on this area indicates a desire by families for robots to support emotional connection and companionship, and thus highlights a potential in-road for social robots to bridge gaps in existing social interactions. A social robot designed to facilitate play while assisting in other areas, such as therapy and education, that resonate with families can enhance its appeal and values to families, making them more inclined to embrace this technology in their lives.

The primary concern raised overall was *safety*, but unexpectedly the concerns were concentrated on specifically the *safety of the robot* itself from harm when used by the child. This contradicted what we expected given previous literature highlighting that guardians of children with disabilities are often overprotective of them [20, 21]. Guardians expressed extensive worry – both how they acted during the study and how they talked about the robots – regarding the children being not careful enough or rough around robots, which may be expensive. Thus, it will be essential to alleviate concerns or worries that guardians may have regarding the fragility and cost of a robot in their homes, for example, through design (the robot looks robust), exposition (tell them it is robust), or by highlighting the potential benefits despite financial risks.

From the perspective of the child's safety, there were some notes about large robots falling or being intimidating to children in their design and requiring acclimation – with suggestions about careful characterization of the robot to avoid such issues. However, we received more detailed concerns over social impacts – such as how the robot would impact play with other children. Some families noted potential barriers linked to their child's disability, which coincides with previous research indicating problems with robot designs not appropriately considering children's abilities [28]. However, our feedback was more social in nature (acclimation, robot appearance, etc.), and the children's physical limitations were not a strong theme. Finally, the children themselves did not independently express any concerns or barriers they would have playing with a robot caused by their disabilities.

We found it encouraging that participant engagement sustained throughout the study, with the discussion, robot ideas, and reflections evolving as the study progressed, and children continually modifying their creations. Evolution happened naturally as the study phases progressed, but also more organically within the family units as guardians and children discussed their ideas and prototypes over time. For example, where a comment from one would spark a new thought or feedback from the other. This self-correction process supported participants to fine-tune their creations, creating a clearer vision of potential robot companions. Overall, this ongoing evolution of ideas and designs provides support for our study tasks and approach for creating engagement, in contrast to, e.g., simply talking to guardians or providing questionnaires, providing a rich and well thought out reflection.

Overall, in reflecting on our results we note that the bulk of the feedback – both potential concerns and use cases – does not involve the child's particular disability or specific challenges or limitations. That is, when developing robot companions to support children with disabilities to play, our results suggest that the primary considerations relating to potential initial adoption may not relate to the child's specific disability, but to more general family and child-type concerns. This contrasts with perhaps specific designs and interventions, which themselves will be likely tailored to a child's specific needs; a designer should thus be careful about hyper-focusing on the disability when considering the overall robot design.

6 Design recommendations

We summarize our findings and discussion into a set of high level design recommendations for people creating social robots to support children with disabilities to play; we leverage our rich study results to provide directions for designing robots to improve their fit to expectations and use-patterns envisioned by families, while avoiding some of the potential challenges.

Emphasize robot robustness, downplay fragility and cost. Perception of robot robustness and low cost should be a primary design goal for social robots to support play, to alleviate guardian concerns, reduce the incidence of parents cautioning and limiting children as observed during our study, and support children to freely interact in a relaxed and natural play experience (important for play [14]. Designers should perhaps favor robustness over tradeoffs such as added features, to reduce cases of robot failure (which have been shown to create negative feedback [28]). Potential additional avenues include robot framing (e.g., telling people that the robot is robust, cheap, or plentiful, etc.), and demonstrating durability (e.g., pushing it over or being rough).

Expect solitary play, design for social. Designs should consider solitary play as a primary use case, given that both our results and previous data show that children with disabilities tended toward doing, and perhaps preferred, solitary play [23]. Even for designs that target or promote parallel, associative, or collaborative play, individual play should be expected and designs should include this, or at least provide individual support as a bridge.

Design for the family and the child, not only the intervention. Include a holistic view of the child, their family, and their home, when designing interventions, even when targeted to a child's particular needs. Our results indicate that these may be more on the minds of families regarding adoption and use than, for example, the child's disability or disability-specific challenges. If possible, learn about each individual child and family; families provided the following suggestions:

Design a play social robot with a familiar form. Leverage a familiar and comforting social robot design (e.g., mimicking a toy or liked animal), to mitigate the fact that many children with disabilities may need extra time or support to transition and adapt to new situations. This may improve comfort which is critical for increasing children's engagement with the robot and promoting a more natural interaction with it. Consider involving the child (e.g., letting them choose) if possible which may allow for increased child-centeredness [31].

Integrate the child's hobbies and interests into the robot. Align robot design, capabilities, and peripheral functions with children's existing interests and play (e.g., sports, arts) to capture attention, leverage existing interactions, and potentially boost engagement. This can serve as an in-road for the child for initial interaction and potential bonding, given the excitement and expectation found in our study.

Design for the social impacts of the robot. Actively design for social impact beyond the targeted design, such as consequences of bringing the robot to a different setting (e.g., a school or park), or attachment issues if lost – these are reasonably to be expected for a play robot. Guardians noted elevated concerns relating to emotional risks for children with disabilities and potential for distress.

Integrate education and therapy activities into robot design. Design a robot to provide support and activities related to a child's required therapies, exercises, or education (perhaps related to their disability) to leverage parental expectations and desires. This may potentially increase guardian or other family member buy-in, providing a catalyst for general adoption and opportunities for the designed-for play support**.**

7 limitations and Future work

This work constitutes the first stage of a larger program to design and develop social robots to support children with disabilities to play. At this stage, we engaged participants with real robots and an in-depth exercise to garner generalizable and broad data that is not limited to specific tasks. However, moving forward will require designing, developing and deploying actual robots into homes. For example, to study the adoption process and phases [58] a family goes through when adopting an actual robot. While this more narrow approach will necessarily limit the generalizability of any results to the robot and task, it will strengthen the data validity and move us closer to actual robot interventions that people use.

To do this, our family-centric perspectives will need to be balanced by the therapy-centric grounding of robot use, for example, by involving perspectives from physiotherapists and occupational therapists via a focus group or other similar methods. Such insight could help round out the family perspective with real clinical or developmental needs, strengthening the resulting design recommendations.

Similarly, our work will need to be expanded beyond our small, targeted sample of children with any disability from Winnipeg, Canada. We will need to increase the number of participants while carefully considering diversity, ensuring that a range of family demographics, backgrounds, and children's disabilities are represented. Further, given that our work is Canada-centric, cross-cultural explorations will help us learn about localized needs as well as generalizable approaches to social robots for play.

While our work emphasizes the potential benefits of social robots for play, one angle we did not explore was the potential negative side effects of adopting companion robots, such as over-use, children inappropriately learning from pseudo-social experiences [59], or the potential for a robot to manipulate children [64]. Broader discussions on actual interventions in homes will need to consider the potential benefits of supporting play with these possible pitfalls of children interacting with social robots.

8 Conclusion

We conducted an exploratory study with children with disabilities and their families, where we engaged participants in a range of tasks designed to engage them in considering a social robot in their homes. Our results provide some of the only grounded insight into how children with disabilities and their families envision adopting a companion robot into their homes, which has been overwhelmingly positive and open to the idea. We summarized our results into concrete design recommendations, intersecting domestic companion robots, children with disabilities, and play, that aim to reduce the need for families to adapt and adjust to these robots; we present to the community to leverage when designing and deploying novel robotic designs.

Although play is crucial for children's cognitive, social, and motor development, children living with disabilities have reduced time for play, leading to a range of potential developmental delays and challenges. Social robots provide a unique opportunity for intervention, and yet, they have largely failed to be adopted into actual use in people's lives and homes. Social robots supporting play will not be successful if we do not solve this adoption and use problem; we need to design and create robots that support play in a task or scenario and are integrated readily into homes and people's daily lives. This paper provides an important step in this direction, as our data and analysis highlight pathways forward toward designing social robots to support play that mesh within existing expectations, desires, concerns, and framings, increasing the chances that social robots for play can actually make a difference in children's lives.

Selection and Participation of Children

This study was reviewed and approved by the <omitted for blind review> Institutional Research Ethics Board as well as the Centre for <omitted for blind review> where the study was hosted. We recruited children through their guardians, recruited through word of mouth, posters at the Centre for <omitted for blind review>, and a drop-by table at the same center. We administered informed consent forms to guardians prior to participation in the study, and a researcher explained the study procedure to the child at the beginning of the session, asking for verbal confirmation that they understood what would take place and that they could end the study at any time. All study sessions took place as a family unit comprising of a child participant and at least one guardian.

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