Investigating Family Perceptions and Design Preferences for an In-Home Robot

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ABSTRACT

Child-robot interactions in educational, developmental, and health domains are widely explored, but little is known about how *families* perceive the presence of a social robot in their home environment and its participation in day-to-day activities. To close this gap, we conducted a participatory design (PD) study with six families, with children aged 10–12, to examine how families perceive in-home social robots participating in shared activities. Our analysis identified three main themes: (1) the robot can have a range of roles in the home as a companion or as an assistant; (2) family members have different preferences for how they would like to interact with the robot in group or personal interactions; and (3) families have privacy, confidentiality, and ethical concerns regarding a social robot's presence in the home. Based on these themes and existing literature, we provide guidelines for the future interaction design of in-home social robots for children.

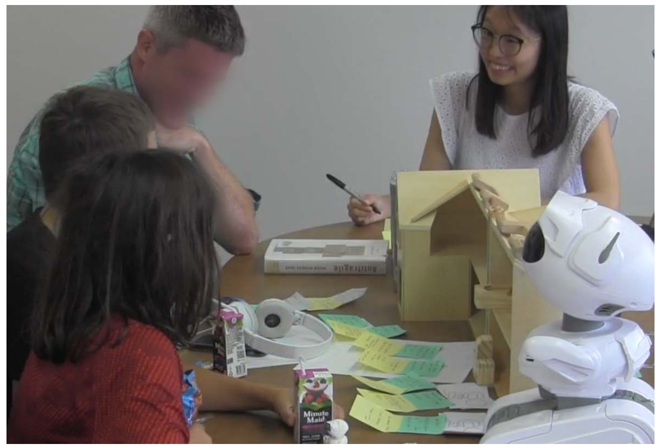

Figure 1: We conducted a Participatory Design study to investigate the design needs of families, including children and parents, for an in-home social robot.

Author Keywords

Child-robot interaction; social robots; interaction design; family-centered design

CCS Concepts

•**Human-centered computing** → **Participatory design;** •**Computer systems organization** → **Robotics;**

INTRODUCTION

Families commonly utilize different forms of home technologies to support their daily activities. Voice assistants such as Alexa or Siri offer users easy access to information, task management, home device operation, and entertainment [4, 25, 37]. In-home service robots, such as the robotic vacuum, Roomba, represent an area of home technology designed to help people with housework, provide disability or chronic health assistance, or provide entertainment [21, 57, 61, 53]. Although voice-assistant and domestic-robot technologies have matured over the past decade and have become integrated into daily lives, the design space for social home robots for long-term interaction is still evolving. To address this need, our research aims to identify the use cases for in-home social robots, focusing on long-term child-robot and family interactions, and to explore user preferences for these interactions.

Social robots share similar verbal communication abilities with voice assistants, but their affordances and capabilities beyond verbal interactions are vastly different. Social robots are embodied [16] and capable of affective expression [31, 50, 36] as well as mobility throughout the physical environment [58]. These capabilities enable complex interactions with humans and the home environment, where the combination of a dynamic physical presence and capacity for active involvement is experienced as being socially meaningful [7]. This multi-modality of verbal and non-verbal interactions requires careful design of in-home social robots to engage in activities in ways that are socially appropriate, natural, and meaningful, particularly as they relate to children.

Research in human-robot interaction (HRI) has demonstrated several use cases for in-home social robots designed to interact with children, including providing assistive interventions for children with autism spectrum disorder to improve their social communication skills [51, 19, 11], coaching children to maintain personal health [30, 54], and supporting children's

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interest development in learning by augmenting reading activities [42]. However, prior work has primarily focused on robot interactions with individual users, and while in-home robots will engage with individuals, they might also involve *multiple family members* (parents, siblings, friends). Given this potential for long-term interactions with multiple members of a household, it is essential to provide personalized interactions and adaptive responses [34] that take into account the myriad of different preferences, perspectives, and goals of the children and other family members with which the social robot may interact.

In this paper, we report on a *participatory design* study aimed to better understand the design space of in-home social robots that engage in long-term interactions with children and other members of a family. We developed several in-home use scenarios for robots and used them to explore families' design needs and preferences in design sessions. By involving children and parents in these sessions, we embraced a family-centered design approach and gained insight into the perceptions of all members of the family. In the remainder of the paper, we present the set up of our design sessions, our findings from these sessions, and design suggestions for an in-home social robot for children.

RELATED WORK

Interactive technologies are widespread in homes, often in the role of conversational agents. People commonly utilize these agents to have simple conversations, ask questions, or receive assistance on daily tasks. Related work shows that in-home voice assistants are incorporated into the day-to-day activities of families [47]. In addition to conversational capabilities of voice assistants, social robots offer greater social presence with their affordances for embodiment, emotional expression, and mobility. Luria et al. [38] compared the usability of a social robot with screen and voice interfaces for a smart-home control system and reported that user perceptions of flow, engagement, enjoyment, and situation awareness were higher for an embodied social robot. In addition, Lee et al. [33] found that users evaluate an embodied social agent more positively than a disembodied one. In general, social robots capable of displaying non-verbal behaviors, gestures, and emotional expressions reduce miscommunication and improve human-robot task performance [8]. Emotion-based adaptations of a robot increase effectiveness for sustaining long-term social engagement for child-robot interactions [2], while mobility in social robots builds affinity with users and increases the perceived likability [58]. Overall, social robots have unique affordances that impact how people perceive them during interactions.

Current research on in-home human-robot interaction has focused on robotic home assistants [15, 14], playmates [1], and socially assistive robots for children [11, 54, 56] or older adults [49, 9, 59]. Work on in-home child-robot interactions suggests that children can benefit from interacting with a robot in social, educational, and developmental domains. Children establish social bonds with robots and have positive experiences during interactions including games and entertainment [5]. At the same time, robot-mediated learning in home environments can improve motivation, attention, and interest of children [39, 24], while reading with an in-home social companion robot can promote children's reading motivation, interest, and comprehension [41, 42]. Long-term interactions with robots can motivate children to perform household tasks, such as tidying their room, and expressive features improve how children perceive the robot [20]. To date, little work has been done to understand the preferences and concerns of other stakeholders, particularly parents and family members in the household, related to interactions with in-home robots.

Research on privacy and information technology suggests that adults often have concerns about maintaining information security and privacy with the use of smart devices [35] or online services [22]. Such concerns are also expressed for in-home robots, where families prefer a home robot to only be located in central areas of the home, due to privacy concerns related to video recording [55]. Other work has reported on teachers' and students' concerns regarding educational robots, including the potential for confidential information to be compromised in the classroom [52].

In the context of long-term in-home child-robot interactions, focusing solely on the design needs and perspectives of the child restricts our ability to explore the appropriate acceptance of the technology in *real* home dynamics. Previous work suggests that designing technologies *for children, with children* [17] allows children to be partners in the design of new technologies [3, 46]. However, family members might also have distinct goals and perspectives about the use of the technology that is sometimes at odds with one another. Researchers can benefit from involving children, siblings, and parents in the design sessions to explore the variation in needs and preferences of different family members.

Prior literature includes a growing number of studies on the design of in-home technologies that follow a family-centered design approach involving the perspectives of parents and children. Christensen et al. [10] conducted design activities with parents and children, such as creating a shared calendar and social drawing, to support family engagement. The authors designed a prototype technology for storytelling which increased the shared experiences of families. Similarly, Hutchinson et al. [26] used technology probes to investigate the social, technical, and design goals for in-home family technologies in multi-generational households. The involvement of multi-generational family members in the design processes facilitated real-life use scenarios and introduced playfulness to family dynamics. Furthermore, Dalsgaard et al. [12] found that including children and parents together in design sessions uncovered unique aspects of parent-child intimacy, such as increased involvement, affiliation, and sense of responsibility. The authors suggest that this unique bond between children and parents introduces challenges when designing technologies for families. Finally, Yip et al. [64] showed that having children and parents participate as co-designers allowed in-depth insight into family interactions in the design of novel technologies. Our work builds on the family-centered design approach followed by these studies and the literature on long-term child-robot interactions to explore the design preferences of children and parents for an in-home social robot.

Table 1: Participant family demographics

Family (ID)	Parent (ID)	Child (ID)
Family 1 (F1)	Mother (P1)	Boy 12 (C1)
Family 2 (F2)	Father (P2)	Boy 12 (C2) Boy 13 (S2)
Family 3 (F3)	Mother (P3)	Boy 12 (C3)
Family 4 (F4)	Mother (P4)	Boy 11 (C4)
Family 5 (F5)	Mother (P5)	Girl 10 (C5)
Family 7 (F7)	Mother (P7)	Girl 11 (C7)

METHOD

To close the gap in the literature on the design preferences of families for an in-home social robot, we conducted a *participatory design* (PD) [44] study with children and parents. Our study included seven families, and each family attended one session with two facilitators. During each session, an individual family shared their day-to-day activities, discussed use-case scenarios for an in-home social robot, and participated in co-design activities for the interaction of an in-home robot. We then analyzed the qualitative data from the co-design activities to synthesize our findings into themes that can inform design recommendations for an in-home robot.

Participants

We recruited seven families through university staff and employee mailing lists (See Table 1). Data from six families with children aged 10–12 years old (M = 11.3, SD = 0.74; *Female* = 2, *Male* = 4) were included in the analysis[1]. During recruitment, we encouraged the participation of additional siblings, parents, or guardians. All families in the study included one parent (*Female* = 5, *Male* = 1), and only one family (i.e., *Family 2*) attended with an additional child (*Age* = 13, *Male*).

Procedure

Every family attended one session that lasted between 2-2.5 hours and included four parts: (1) individual interviews (20 min), (2) family discussions (30 min), (3) design resources personalization (10 min), and (4) the co-design activity (1-1.5 hr). The first two authors facilitated the design sessions.

Materials

Overall, we employed *fiction as a resource* [32] in our design sessions by using a range of materials[2] (i.e., sticky notes, miniature figurines, a dollhouse, and a social robot) to create a fictional space for children and parents to imagine and design interactions with an in-home social robot. For interviews and discussions, we used sticky notes as a resource to report participant scenarios. For the co-design activity, we adapted a user-centered design method by providing miniature figurines and a dollhouse with furniture as a form of *miniature play* [28, 60]. We also used a programmable personal robot, Misty[3], left in a powered-down state during the study, and a 3D printed miniature version of the robot to help participants in demonstrating interactions with a robot. Throughout the sessions, we took notes in the form of audio/video recordings and drawings (See Figure 3).

Figure 2: Materials used during the design sessions: powered-down social robot, doll house, furniture, miniature figurines, sticky notes, and drawings.

1. Individual Interviews

We first conducted individual interviews with parents and children separately, to reduce parental influence and gain authentic insight from the children, about the in-home daily life activities of the child. We asked each participant to list these activities and the interviewer wrote each activity on a sticky note. For each activity listed, we asked two follow-up questions; *who else attends the activity,* and *where does the activity take place in the house*. When the interview was completed, we defined the activities on the sticky notes as *"scenarios."*

2. Family Discussions

After the individual interviews, researchers and family members rejoined for a discussion activity. We shared all the scenarios from the individual interviews and encouraged family members to discuss their scenarios. Following the discussions, we asked family members to rank the scenarios based on how frequently it occurs in their household. After recording the ranking of the scenarios, we provided our definition of a *social robot* for the families (i.e., we explained that a social robot is capable of interacting with people through verbal and non-verbal communication skills; it can carry different social roles in the household; and it can act as child's personal robot or as a family robot). Later, we asked family members to select the scenarios in which they would include a social robot. We used the selected scenarios to shape the discussion points for the co-design activity.

3. Design Resources Personalization

After the family discussions, we provided snacks and beverages for families during a short break. During the break, we introduced the following design resources: *miniature figurines,*

[1]The data from *Family 6* was not included in the analysis because the session ended prematurely due to personal circumstances of a facilitator.

[2]The resources used for design sessions are listed in the repository www.github.com/bengisucagiltay/IDC2020_Resources

[3]www.mistyrobotics.com

Figure 3: *Note taking in the form of drawings:* During the co-design activities a facilitator illustrated families' design preferences to facilitate discussions

a dollhouse, and *furniture sets*. Family members created representative figurines of people that were involved in the scenarios and organized the dollhouse according to their preferences.

4. Co-design Activity

For the co-design activity, we introduced the powered-down Misty robot, its 3D-printed miniature version (See Figure 2), and we briefly described the capabilities of the robot (i.e., the robot has cameras for object and face recognition, a screen to display a range of emotions, speakers and a microphone for verbal communication, and proximity sensors to avoid obstacles while moving). We then explained our focus on designing the interaction, rather than the physical attributes of the social robot. We avoided assigning any social roles to the robot and provided an option for family members to name the robot themselves or use the commercial name.

For each scenario, we asked family members to describe how they would include a social robot and act out the interaction with the provided resources. To facilitate discussions with children and parents we utilized probing questions such as, *what do you like or dislike about this scenario including the robot; how would you want the robot to interact with you and your family; what would you like the robot to say or do in this scenario*? While family members discussed and demonstrated the scenarios, one of the researchers took notes in the form of drawings (See Figure 3). The researcher summarized each design idea with a visual representation and facilitated discussions using these illustrations to ensure mutual understanding of the interaction. The co-design activity ended after the family discussed all scenarios, suggestions, and preferences.

Qualitative Analysis

We conducted a reflexive *Thematic Analysis* (TA) on the data from the co-design activities. We did not include the individual interviews and family discussions in the analysis since the focus of those activities was to generate activity scenarios for the co-design sessions. For the thematic analysis of the co-design sessions, we followed the guidelines presented by Braun et al. [6] and Mcdonald et al. [40]. The first two authors familiarized themselves with the data by having facilitated the design sessions and subsequently through transcribing and reviewing the session recordings. The authors initially generated potential codes individually and regularly discussed all candidate themes together, later revised and combined related themes, and then generated a visual map of the thematic concepts that emerged from the data. Finally, the authors reviewed, defined, and reported the themes as findings.

Themes	Categories	Examples
Role in the Home	Robot as a companion	Playmate Reading companion Conversational companion and confidant
	Robot as an assistant	Cooking, instrument or homework assistant
Preferences on Interactions with the Robot	Group interaction preferences	User priorities and authority Timing of the interaction
	Personalized interaction preferences	Adapt to the knowledge and relationship level of the user Customize the name and speech of the robot
Concerns about the Robot in the Home	Privacy concerns	Confidentiality and information sharing
	Ethical concerns	Educational use of robots

Figure 4: Themes generated from Thematic Analysis: (1) A social robot can have roles as a companion or an assistant in the household, (2) Family members have preferences on individual or group interactions with the robot, (3) Family members have privacy and ethical concerns for in-home robots.

RESULTS

As a result of our analysis, we identified three main themes (See Figure 4) that emerged for the interaction design of a social home robot: (1) Families perceive a social robot's role in the house as a *companion* or as an *assistant*. (2) Family members have preferences on the robot's priority management and interaction timing in *group interactions*, as well as *personalized interactions* adaptive to the knowledge level or relationship level of the user, including a customized speech and name for the robot. (3) Family members have *privacy and confidentiality* concerns on shared information in family conversations involving the robot and *ethical concerns* about the educational use of robots. We elaborate on each theme with quotes and observations from the co-design activities. To attribute quotes to participants in this report, we use participant IDs (See Table 1) where family groups are identified with a number along with a P for parent, C for child, S for sibling, or F when referring to the whole family. For example, the parent in Family 1 would be identified as *P1*; the child in Family 2 would be identified as *C2*; the sibling of *C5* would be identified as *S5*; *P7*, *C7* and *S7* would be from the same family group, and *F4* would refer to Family 4.

Theme 1. The Robot's Role in the Home

We identified two main roles for an in-home social robot that emerged from our analysis: (1) robot as a companion, (2) robot as an assistant. The role of a companion reflected personal social connections with children at a peer level, while the role of an assistant administered supportive services in the home that often took the shape of a tutor, such as providing instructions and information.

Robot as a Companion

Through our thematic analysis, we identified three roles for a home companion robot: (1) playmate, (2) reading companion, and (3) conversational companion and confidant.

Playmate — All six families discussed the robot's role as a playmate in their family activity scenarios (i.e., board games, guessing games, doll games, dress-up games, dancing, trivia, video games, or sports). In discussions where participants described the robot as a playmate, children *C2, C3,* and *C5* often perceived the robot more as a peer rather than a device or toy. For example, *C5* described the robot as a *"buddy"* and stated,*"[the robot] should be playing with me if he is a companion, instead of just being a dictionary. Dictionaries are boring, and I don't want [the robot] to have to be boring." F2* and *F3* wanted the robot to participate as a helper or a strategy and rule provider for family activities. For game nights, *C3* suggested that if all members are unfamiliar with a game, the robot could *"explain the game in an understandable way to everyone"* and if there is one novice player in the room the robot would provide individual strategies. *P3* supported *C3*'s opinion by stating, *"it could be better for [the robot] to offer strategies privately, so not everyone knows the strategy." C1* and *C4* wanted the robot to coach them for their sports training. All parents supported the role of a playmate except *P7* was strongly against the idea of having a social robot during their game night activities due to their family rule of *"no electronics during game night."* In general, based on our PD sessions, it appears that families viewed the robot as a facilitator or helper when interacting with them during play, but that the robot would occupy a peer and playful role in these interactions.

Reading Companion — Families *F2*, *F4*, and *F5* discussed the role of the robot in reading scenarios. *F2* and *F5* provided design suggestions focused on speech, intonation, expressiveness, pronunciation, and vocabulary support features for a reading companion robot, while *C4* assigned the role of an audio-book for the robot. While reading, *C5* wanted the robot to give definitions to difficult words and also wanted to teach the robot *"surprising, non-surprising, and sad things"* about books so that the robot could express appropriate emotions. *F2* proposed that the robot could suggest books, provide comments after reading a part of a book, and engage in interactive reading and guessing games. Overall, families appeared to have a variety of ways that the robot could participate in reading activities with children. In each of these suggestions, the robot was perceived as a companion in the activity that could support reading comprehension or motivate the child through emotional expressions and guessing games.

Conversational Companion and Confidant — Families *F1*, *F3*, *F4*, and *F7* discussed scenarios involving the robot in family conversations. *C7* perceived the social robot as a peer and wanted to converse about hobbies, movies, daily events, and trivia facts. *C1* expressed that it would be useful *"if you want to have a conversation with somebody, but if nobody is there." F4* elaborated on the role of a social robot as a confidant. *C4* described the robot as a *"trusting companion"* and suggested that the robot could give *"one-on-one therapy"* without the child being worried about the robot breaking confidentiality. *C4* wanted to be able to conceal his feelings and wanted the robot to help work through them *"I would never tell that to a camera. But I could tell that to [the robot], and [the robot] would not tell the other person." P4* supported the conversational role for the robot and stated, *"you could have a friend to talk to. You can talk more to the social robot." P7* and *P3* did not want the robot to be involved socially in conversations during family dinners, but *P3* indicated that the robot could play dinner music. In general, the children saw the robot as a social interactor that could participate in activities as a friend or as a conversational companion and wanted to be able to share secrets, open up about their feelings, and establish a trusting bond between the robot. Parents expressed concerns about certain family social interactions, particularly dinners, that the robot should avoid participation.

Robot as an Assistant

Through our thematic analysis, we identified three main activities for a social robot, including (1) cooking assistance, (2) instrument practicing, and (3) homework support.

Cooking Support Assistant — All six families discussed the social robot's role in a cooking scenario. Parents *P2, P3, P4, P5* and all children wanted the robot to give step-by-step instructions for a recipe. For example, *P1* and *P4* suggested that the robot should recommend recipes based on the available ingredients in the pantry, and *C1* wanted the robot to provide customized instructions based on the dietary restrictions of family members. Although parents mostly supported using a cooking assistant robot, *P1* and *P7* also highlighted that, in some cases, the robot could get in the way in the kitchen. *P7* stated, *"I just don't see [the robot] being helpful in a confined space."* In general, for scenarios taking place in the kitchen, parents and children viewed a social robot as an assistant for providing recipes or instructions for customized dietary support and food preparation. At the same time, two parents were uncomfortable with the idea of having a social robot present in the kitchen space.

Instrument Support Assistant — Four families (*F1*, *F2*, *F4*, and *F7*) discussed having a robot as an assistant for the child's instrument practice. *S2* expressed that the robot could help with tuning the instrument, while *C2* stated that the robot could demonstrate a song or collaborate in an ensemble. *C1*, *C4*, and *C7* wanted the robot to provide guidance while playing the instruments, and *C1* wanted the robot to correct the usage of the instrument. *C7* wanted the robot to accompany her during her music lessons and later give recommendations based on teacher suggestions: *"[the robot] could remind [me] when I'm at home. Like 'during your lesson, [the music instructor]* *told you to do an up movement instead of a down movement, so maybe that's what you should try."* In general, our results from the design activities show that children wanted the robot to be an assistant able to give music advice and accompany children during music lessons or practice sessions.

Homework Support Assistant — All six families suggested a supportive homework assistant role for the robot. *P1, P2*, and *P5* emphasized that the robot could provide information or explain terms to children to support their learning. *C3* expressed that a robot can motivate children to finish their homework on time, while *C4* and *C7* wanted the robot to test a child's understanding of a concept. Overall, for scenarios including homework, children wanted a social robot to provide definitions, explanations, supportive information, and motivation.

Theme 2. Preferences on Interactions with the Robot

As a result of our design activities, we divided in-home family interactions under two main categories: (1) group interaction preferences, (2) personalized interaction preferences

Group Interaction Preferences

Family scenarios with an in-home robot involved group interactions with household members (i.e., parents, siblings, or friends). Group interactions with an in-home robot included family discussions on (1) priority management between group members and (2) interaction timing of the robot.

Priorities between group members — As a result of our analysis, we observed that all six families assigned priority levels for the robot to convey under a group setting. In regular interactions, all children wanted a first-come first-served interactions under group settings; however, families (*F3, F4, F5, F7*) also discussed cases which might require parental override. *C1* stated that the person who first initiated an interaction (i.e., *"the leader"*) would be in charge of adding new members to a group interaction. However, a person with higher priority, such as a parent, would be able to join without any permission. Similarly, *C3* and *C4* suggested that the first interactor would be in charge of the robot's ongoing interaction, but other family members might be able to override. *C3* distinguished the priorities between the *"owner"* and the *"first interactor"* and summarized as: *"in a perfect world, I would like levels of priority. And for any scale, being the owner adds [a certain] amount of priority to anything asked."* For example, *C3* assigned a priority level of 5 to homework, 6 to work, and an additional 2 points for the owner. *C3* later stated, *"if [the robot] is helping somebody with work, and if the owner asks for help with homework, then the owner gets automatic priority to the person that was already using [the robot]." S2* wanted the homework assistant robot to answer children's questions in the order they were asked: *"[the robot] finds out who ends first, will answer [his or her] question, and then will answer the second one." C5* wanted to customize user priorities based on the age of the users or complexity of the task. For example, *"[the robot] can talk to both of us. We could program [the robot] to go to either the youngest person first or the oldest person first or the person with the hardest word."*

Parents often expressed their opinions on customizing a hierarchy level for the robot's priority preferences. *P5* stated, *"I would prefer it being able to set a hierarchy. Mom and dad, their word goes no matter what, and then set C5 and S5 equal."* Likewise, *P7* stated, *"personally because I am the authority figure, the robot should listen to me because if we tell you all to do something, you C7 and S7 should do it." P3* wanted the robot to have custom priority preferences for either the task or the person such that *"if there is a family member who needs more help than other family members, by [his or her] age or disability or any other sort of thing that maybe there is a way to prioritize the person too."* Overall, our results show that families wanted a social robot to prioritize among members depending on the state and importance of the task, or the age, hierarchy, and role of the person, along with the ability to customize the priority levels of the robot.

Timing of the robot's interaction — *F1*, *F2*, and *F4* discussed when and how frequent the robot should initiate an interaction or split its attention during an activity. *P1* did not want the robot to initiate an interaction unless a user asked for it: *"I don't want [the robot] to butt in. I don't want her to say anything unless we specifically ask of it." C1* suggested that the robot could interrupt conversations if none of the members is opposed to this setting. *P4* wanted the robot to remind children about their homework every few hours and *C2* wanted the robot to offer assistance every half hour, with the option to mute the robot if needed, while *P2* contrarily stated, *"I wouldn't like that. I would speak for myself."*

Families *F1*, *F3*, and *F7* discussed whether the robot should greet new people during an ongoing task. Parents (*P1, P3*, and *P7*) expected the robot to interact with or at least greet other members in the room. *P7* stated, *"I think it would be weird if [the robot] just interacted with one of us."* Likewise, *P3* stated, *"it's typical with our family, we acknowledge. [The greeting] could be in line with how our family communicates."* For homework scenarios (*C3*) and cooking scenarios (*C1*), children did not want the robot to greet new people. However, after family discussions, children suggested that the robot could shift attention to new people only after completing the ongoing activity (i.e., after the robot finished answering the child's questions, or after the child finished cooking and left the room). Overall, for group interactions, family members had conflicting opinions on the timing and frequency of which the robot would initiate an interaction or greet new members.

Personalized Interaction Preferences

As a result of the design activities, families wanted a social robot's interaction to be adaptive to the user's (1) knowledge level and (2) relationship level. The design discussions also included preferences for customizing the (3) speech, speech content, and (4) name of the robot.

Interaction adaptation to the knowledge level of the user— All families except *F2* discussed a personalized and adaptive response of the robot based on the knowledge level (i.e., expertise or age) of the user. *C3, P4*, and *C5* wanted the robot to provide recommendations to users based on their skill level. For example, *C5* mentioned that her father is not highly skilled in cooking and would need explanations in simpler terms from the robot. Similarly, *P4* expressed, *"[the robot] is not going to tell me if the Wi-Fi is out because [the robot] knows I am not going to repair it well."* In the context of board games, *C3* and *C5* wanted the robot to give instructions based on players' expertise level. Families wanted the robot to give word definitions (*C1* and *C5*) or task instructions (*P7*) in different complexities to parents, children and younger or older siblings. *C1* also wanted to be able to select the difficulty of the robot's response. For example, *"[the robot], can you define this word using simple terms? Explain like I'm five [years old]."*. *C4* wanted the robot to suggest a movie or a book depending on the age of the person: *"[people] your age have tended to like reading this book. Have you considered reading this book?"* In general, children wanted the robot to have an adaptive interaction for different expertise levels or age ranges of users.

Interaction adaptation to the relationship level of the user— *C1*, *C4*, and *C5* discussed scenarios in which the robot's interaction differed based on the relationship level of the user (i.e., friends, family, or strangers). *C4* stated that the amount of time that a person spends with a robot could influence the robot's reaction, such that the robot would interact more with grandparents compared to friends because the robot would be more familiar with relatives. *C5* suggested that the frequency of the interaction can trigger a personalized interaction. For example, a speech accent mode of the robot would be activated for a friend that visits *C5* more often. *C1* wanted the robot to assign importance levels to different users: *"maybe the parents are the most important, and the family, and then maybe some friends, and then acquaintances, visitors."* *C4* wanted the robot to avoid strangers and *"hide in the corner."* Overall, children wanted the robot to assign a relationship level to users and adjust its interaction based on the assigned level.

Speech and speech content of the robot — Children *C2*, *C3*, *C5*, and *C7* discussed speech attributes for the social robot. *C2* wanted the robot to adjust its speech based on the responses during the interaction: *"I'd probably design it to say multiple things and see which one translates to the best experience that people are having with it."* *C3* wanted the robot to have variability in it's tone of speech. For example, *C3* wanted the robot to have a *"softer tone"* while assisting with homework and *"a more aggressive and encouraging tone"* while someone is exercising. *P4* wanted the robot to have motivational speech, like *"come on buddy, do your homework!"* For the robot's role as a reading companion, *C5* wanted the robot to give appropriate linguistic expressions to a book's plot: *"[the robot] would have this surprised expression. He would be like AHH!"* *C5* also wanted users to be able to adjust the expressiveness of the speech for the robot to *"sound sad or sound happy or sound angry"* or adjust the attitude of the robot by telling it *"to be nice or be sassy or to be rude."* Similarly, *C7* wanted the robot to be *"more like a human which it has to have a little bit of annoyingness in it."* However, *C4* and *C7* did not want the robot to use critical speech during activities, particularly for their hobbies. *C4* explained, *"[the robot] critiquing is a very different thing than [the robot] working with me. I don't want [the robot] to give me advice out of nowhere."* Similarly, *C7* stated, *"I want someone who knows what I am doing and doesn't lecture me about what I am doing wrong"* and wanted to ask the robot for suggestions *"rather than having [the robot] just say it."* The overall results show that children are in favor of a robot capable of customizing its tone or emotional response depending on the nature of the interaction or personality of the robot.

C3, C5, and *C7* discussed other aspects of speech design, such as language, accents, and humor of the robot. *C7* wanted families to have different language options for the robot. *C5* wanted users to customize the accent: *"[the robot] would have a British accent to me and to everyone else it's talking to has an Australian accent."* *C3* and *C7* wanted the robot to have humor. *C3* suggested that the robot could observe the types of jokes in the family and *"would be able to tell jokes personalized to each person."* However, *C7* wanted jokes not to be distracting: *"I would want to socialize with [the robot] but not want it constantly making jokes and distracting me."* Overall, children wanted the robot to have language settings, different types of accents, and a personalized sense of humor.

Naming the robot — *C1*, *C3*, and *C7* referred to the robot as Misty. *C2* referred to the robot as *"Ritchie"*, and *S2* referred to it as *"Bubby"* during the family discussion stage of the study, prior to seeing the robot. However, *C2* and *S2* decided to use the name Misty when they saw the robot for the design activities. *C4* named the robot *"Jenbot"* – by combining a part of *P4*'s name[4] and the word *"bot."* *C5* addressed the robot mostly as *"Bob the Second."* However, *C5* assigned different names, accents, and personalities to the robot and stated, *"different names mean different things."* *C5* assigned an Australian accent to *"Bob the Second,"* a British accent to *"Charles,"* and alternated between these roles of the robot during the design activities.

Theme 3. Concerns About Having Robots in the Home

Parents and children expressed their concerns about a social robot at home related to the (1) privacy of family conversations, and (2) ethical concerns about the educational use of robots.

Individual or Group Concerns on Privacy and Confidentiality

Privacy and confidentiality concerns were vocalized only by parents *P1*, *P2*, and *P4* during the design activities. The issues were mainly related to the confidentiality of information shared between family members and the robot. *P1* and *P4* expressed concerns about the potential risk of which the robot might share personal conversations or confidential information with other members, such as friends, family, or visitors. To resolve this concern, *C1* suggested that the robot could have different adjustable levels of confidentiality for every user and would not share private information to anyone below a given *"importance level."* However, *P1* also wanted a parental mode to be able to monitor the child's activities with the robot. *P4* stated, *"I don't want [the robot] to know the conversations that we are having about Grandma"* and to elaborate on this confidentiality concern *P4* suggested, *"I trust you C4, and you trust me that I am not going to tell Grandma. We could trust*

[4] P4's actual name was replaced for anonymity.

the robot by turning it off." P2 often highlighted privacy concerns towards other smart-home technologies and expressed his preference towards minimal usage of voice assistants and Internet of Things (IoT) devices. *P2* stated, *"I can't see myself accepting a social robot in the house in the first place. I would have to know a lot about it"* and *P2* wanted to have *"primary control of the robot."* To summarize, families expressed their concerns towards the potential risk of an in-home robot revealing personal conversations or information to other family members, users, or third-party services.

Ethics Surrounding the Educational Use of Robots

Children *S2, C3*, and *C4* expressed ethical concerns towards using a homework assistant robot, such that it may affect the learning process or cause unfair advantages among peers. For an in-home robot capable of assisting with homework, *S2* stated that *"[teachers] might consider it cheating or getting an upper hand"*, and similarly *C4* expressed that, *"[it] might not be the way that the math teacher wants."* Additionally, *C3* stated that the robot would not be allowed to do homework for children, but it could provide *"help from time to time."* Overall, children discussed their ethical concerns about the use of a homework assistant robot, which would create limitations on the extent the robot's involvement in educational activities.

DISCUSSION

In this study, we sought to further our understanding of how to design an in-home social robot for long-term interactions with children that accommodates the goals and perspectives of multiple family members. The results from our participatory design sessions demonstrate how families pictured reconciling their different preferences for the robot's role in their daily life activities and provide valuable insight regarding the design implications towards the acceptance of a social robot in the home (See Figure 5). Involving a social robot in daily life activities, children and parents discussed the roles of the robot as a *companion* or an *assistant*. For group interactions with the robot, family members wanted the robot to have an *adaptive behavior* with personalized responses that varied based on the composition of the group. Family dynamics led to discussions about *authority* and who controls the interaction, along with *priority* settings, to manage conflicting states. Parents addressed *privacy concerns* related to the involvement of a social robot in family conversations and how the robot would maintain the confidentiality of the information shared among family members or other users.

These findings provide a unique perspective on designing for in-home multi-family member interactions, where we suggest that access to priority settings and rapidly dynamic personalization are key. Little prior work examines the role of the robot in shared (i.e., parent-child) activities, and this work begins to explore the design preferences of families for in-home robot interactions within this shared space. Here, we discuss how our results support and expand prior work and share the design implications of an in-home robot by examining the dynamics of family interactions.

Design Recommendations for an In-home Robot

Roles for the Robot in the Home: Provide a set of adaptive roles for the robot reflecting family members' preferences in the home.

- For interactions with **children:** Assign the role of a trustworthy *peer* or friend to play, read, and talk to.
- For interactions with **parents**: Assign the role as a supportive *assistant* for daily tasks and reduce social interactions.
- For interactions with **children and parents:** Assign the role as a *facilitator* and information provider for shared family activities.

Group Interactions: Provide personalized responses and behaviors for the robot that dynamically adapt to the group composition during interactions.

Authority: Allow users to set family-specific rules, authority and hierarchy preferences, and provide default parental privileges.

Priority: Provide default settings for managing priority conflicts in group interactions that can also be customized by users.

Privacy of Family Conversations: Allow users to assign family-specific confidentiality levels to the members in group interactions.

Provide privacy settings for the robot to follow in family conversations.

Figure 5: We summarize the design recommendations for an in-home robot emerging from the perspectives of children and parents.

Family Perspectives for the Role of an In-Home Robot

Children were interested in interacting with an in-home robot in deeply social roles that go beyond learning and play. Children (*C1, C3, C4, and C7*) felt that the robot could listen to and sympathize with them and help them work through thoughts and feelings. This finding extends the scope of child-robot interaction from prior work, which has suggested that social connections with robots may develop over time [42] and that robots might be useful as conversational agents [9, 56]. It may be that the potential for these connections invokes children's desires to interact at a more profound social level than previously thought. One child (*C4*) explained his desire to confide in the robot was because he felt that the robot would not judge him or break his trust. This neutral, trustworthy relationship that a social robot offers may be beneficial for children who are growing socially and emotionally but is also a relationship that must be carefully designed. Future work will need to be conducted to explore how to appropriately and ethically design these types of interactions in ways that benefit children, such as providing empathetic support during interactions [36], while also removing or minimizing the risks in developmental effects, human replacement, and privacy concerns [52].

Children in the study described robot interactions that support social activity and development in roles such as playmates [1] or learning aids [39, 41]. Parents, in contrast, showed less interest in these social agencies for the robot and preferred to utilize the robot as a supportive assistant during their imagined interactions. Parents often supported roles for the robot that was akin to roles for voice assistant technologies found in previous work [14, 15, 43], such as reading recipes in the kitchen (*P2, P3, P4, and P5*) or as a homework assistant providing word definitions (*P1, P2, and P5*). Furthermore, for more complex or long-term interactions, children (*C1, C2, and C3*) wanted to have regular social interactions with the robot that were prompted by the robot, but parents (*P1, P2, P5, and P7*) wanted to be in control of deciding when and how much individual interaction that they would have with the robot, and did not want to receive prompts from it.

When families pictured activities the robot would engage in with *multiple* family members, the activities did not directly relate to, or focus on, the robot. Instead, these were activities that families already did, like playing games or practicing music together. In these scenarios, the robot was seen as a facilitator to support a family activity, such as explaining how to play a game or monitor whether instruments are in tune, rather than be the primary focus of the activity. However, when appropriate, the robot was seen as a peer for children which would engage directly in activities, such as reading a book, cooking, or playing together. In these cases, children (*C1 and C3*) wanted to be the robot's center of attention and did not want it to interact with others in the environment, while parents (*P1, P3, and P7*) expected the robot to engage with others. These types of conflicts led some families (*F1 and F3*) to compromise and suggest an interaction design for the robot that would mutually satisfy them, such as waiting until the ongoing task is completed to acknowledge other users.

Individual design choices of children, such as naming the robot, also highlighted factors that influence the perception of a personal robot in the home. Related work shows that humans feel more empathetic towards a robot with a name and personal back-story [13], and in robotic competitions naming the robot contributes to its identity construction and ownership relationship between the users [29]. Children assigning names to the robot might potentially strengthen their bond between the robot; however, it might also prevent the robot from being perceived as a peer, and more as a toy or pet. Children in our study who named the robot (*C2, S2, C4, and C5*), and who used the commercial name (*C1, C3, and C7*) both assigned socially situated roles for the robot, as a companion or playmate. On the other hand, children also had alternating perceptions for the robot concerning its name, such that one child (C5) assigned multiple names and multiple personalities to the robot while *C2 and S2* decided to switch to the commercial name after seeing the robot. These results imply the need for further investigation on the impact of naming a robot, such as how factors like physical appearance and perceived personality contribute to how children would name the robot, and the interaction effects of the name and other characteristics on developing social connections with the robot and acceptance of the robot within the family.

Design Recommendations. Design considerations for in-home social robots should accommodate the diverse preferences of children and parents to facilitate long-term interactions and acceptance of the robot. Based on the differences in desired roles of the robot, we suggest designers to incorporate an **adaptive set of roles for the robot reflecting family members' preferences.** When interacting with *children*, we suggest that the robot should act as a trustworthy peer or a friend. Additional research is needed to identify details of how to ethically and beneficially enact these roles with children, but our design sessions present a clear desire for deep social bonds in child-robot interactions. For interactions with *parents*, it may be best to reduce social interactions and deliver assistance to increase utility and efficiency in daily life activities. When interacting with both *children and parents*, families seem to prefer the robot to act as a facilitator. Therefore, we recommend the robot should be designed to provide supportive and useful information to everyone involved in the interaction, such as the rules of a game or event reminders, but also provide socially interactive support for children, such as giving hints on game strategies or being playful during chore activities.

Designing for Group Interactions

The inter-family discussions and compromises which arose during our design sessions demonstrate critical insight into how real-world interactions might play out within the home. For group interactions, family members suggested dynamically personalized interactions that could rapidly change depending on the composition of family members involved in a group activity, particularly based on their *relationship level* (i.e., parent, child, relative, friend, or stranger). Children (*C1, C4, and C5*) suggested that, as the robot learned more about household members and built relationships with them over time, it would change its interaction to match the users' preferences and personalities. For example, a robot that displays a default interaction upon first meeting would later behave in more familiar and tailored ways after more frequent interactions with the individual. These findings are in line with related work for personalized robots, including adaptive speech complexity [63], linguistic style [48], expressiveness [50, 23], accent [27], pitch and humor [62, 45]. However, these detailed adaptations and personalizations expected by family members might be challenging to design for complex group interactions. Little work has yet to explore this dynamic adaptation of robot behaviors in group settings, and require new areas of research on multi-family member robot interactions.

Design Recommendations. We suggest designers to focus on ways to **personalize multi-family member interactions by accommodating individual desires and needs**. Utilizing heuristics-based approaches supported by user feedback, coupled with factors such as the user's interests, activities, or average interaction time with the robot, might be useful in developing personalized interactions for individuals. These personalized interactions can later be used to **dynamically adapt interactions within different group compositions**, for example, the robot can identify common or conflicting preferences of group members and optimize the interaction by weighing in these preferences.

Social Robots in Family Dynamics: Authority and Priority

Families discussed design factors that would influence the acceptance of a social robot in the home, including priority and authority settings, which led to productive discourse on compromise in multi-family member interactions. Family members focused on ways to explicitly prioritize and weigh the conflicting goals of each member, which helped frame the activities in which the robot could engage. Families (*F1, F3, F5, and F7*) felt that parental preferences would take priority when desired and could override children's preferences. To this end, children and parents found equitable ways of respecting each other's goals of interaction with the robot. For example, children (*C3, C4, and C7*) wanted the robot to spend social time with them as a conversational companion, and the parents in these families supported their child's preference for this role. However, parents also believed that the robot should still adhere to family rules and norms, including limits on the use of technology, particularly during shared meals (*P3 and P7*). To maintain the balance of new family dynamics involving a social robot, parents (*P5 and P7*) wanted to have authority in determining whose goals and preferences to prioritize when in conflict. Families (*F3 and F5*) suggested ways to determine priority based on the differences in age or need for assistance and wanted to have explicit control over the parameters for priorities. One child (*C3*) suggested that mechanisms for determining weights and priorities for deciding whose preferences should be followed when conflicts arise. These findings have not been explored in prior work, and our study establishes an area of future research to better prioritize family-robot interactions engaging multiple parties.

Design Recommendations. While no two families completely agreed on one set of priorities, the unique dynamics of each family revealed the need for family-controlled settings. Through carefully curated user profiles, parents and children would benefit from having the **option to set boundaries, limitations, house rules, and family hierarchy preferences**. For maintaining authority, as families (*F1, F3, F5, and F7*) suggested, we recommend designers to provide default **parent privileges for interactions**, which parents can access and adjust through user-profiles and authentication methods, such as face recognition. However, it is also crucial for designers to seek equitable ways to provide authority settings while maintaining the trust and bond between the child and the robot. For example, the robot should not impose family rules on the child but take a peer-like approach by suggesting and reminding pre-set house rules and authority settings. To resolve priority conflicts in group interactions, we suggest designers to provide **default settings for the robot to manage the priorities of group members**, along with **options for users to personalize these priorities**. These settings can include scheduling options such as first-come-first-served or priority queues based on the activity type and time spent on each interaction per family member. Additionally, adaptive feedback mechanisms to improve family-specific priority management over time can be beneficial for the acceptance of the robot in long-term interactions.

Exploring Family Concerns for In-Home Robots: Privacy of Family Conversations

During our design sessions, parents and children articulated a set of concerns related to privacy issues that emerge from the dynamics of multi-family member interactions with a social robot. A valuable insight was that parents (*P1 and P4*), but not children, were concerned about the confidentiality of private conversations among family members with the presence of a social robot. Typically, privacy concerns towards technology have focused on how data collected might be shared outside the home and online [22, 35], yet parents expressed that it would be problematic if a robot would share the information from group interactions with other members in the home. One parent (*P1*) suggested the need for a parental mode on the robot to monitor what information the robot has collected from conversations and prevent the robot from divulging information, while the child (*C1*) suggested defining an *"importance level"* for each user and assigning *"levels of confidentiality"* would be beneficial in order to manage these privacy concerns.

Design Recommendations. The issue of how a social robot should handle information shared in multi-family member interactions has not yet been explored, and our study introduces a design space related to investigations that can enlighten parent and child perspectives on privacy and confidentiality concerns for in-home group interactions. To address family members' privacy concerns, we suggest designers to provide **custom confidentiality levels that can be assigned to different family members or others interacting with the robot**. In group interactions, the robot should attempt to distinguish the relationship between group members and identify the confidentiality level for each individual; otherwise, it should conform to a default privacy setting. Families can set limits on what and how much information can be shared about a member of the home, as well as what and who this information can be shared with in and out of the home.

Limitations and Future Directions

The small sample size of our study and the narrow representation of ages and genders limit the generalizability of our findings. Our study includes children in the age range of 10 to 12 and the representation of mainly mothers and sons. Future work should actively recruit a better balance of genders and expand the age range to yield additional insight into family preferences for the design of a home robot. We found that conducting our study in a lab setting helped to standardize the procedure; however, it also limited how well families were able to describe their home activities while away from home. We plan to conduct future work in the field to explore these interactions in real-world settings. Finally, the role of children and parents in our PD sessions was at the informant level [18] that produced insight on individual preferences and perspectives, but families did not see a functioning robot or how their suggestions might appear with a robot. This inability to demonstrate the suggestions limited our ability to have families accurately reflect on how they would realistically experience the interaction. We aim to conduct future work in which we rapidly program design suggestions for families to experience and reflect.

In summary, our exploration of family perceptions and preferences towards the design of an in-home social robot broadens the knowledge of how family members have competing goals and expectancies when interacting with a robot and how these conflicts might be resolved. Our goal is to utilize these insights from children and parents to design interactions for social robots and evaluate in-home multi-family member interactions with longitudinal field studies.

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SELECTION AND PARTICIPATION OF CHILDREN

Children were recruited through parents who were contacted through university employee mailing lists. The main inclusion criterion was families with at least one child aged 10–12. For the consent process, researchers described the study along with how participants' confidentiality would be protected in publications (i.e., any identifiable information will be removed or anonymized from the data, including videos, images, or transcribed speech). After researchers obtained written consent from parents, a written assent form was read to the minor(s). Children and parents were encouraged to ask questions related to the study procedure. The study was initiated only after the minors consented to participate and signed the assent form. After the completion of the study, the parents received $30 compensation for their time. The study was reviewed and approved by the University of Wisconsin–Madison Institutional Review Board (IRB) under protocol 2019-1460, "STEMMates: Designing Educational Robots for Children."

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