"Off Script:" Design Opportunities Emerging from Long-Term Social Robot Interactions In-the-Wild

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ABSTRACT

Social robots are becoming increasingly prevalent in the real world. Unsupervised user interactions in a natural and familiar setting, such as the home, can reveal novel design insights and opportunities. This paper presents an analysis and key design insights from family-robot interactions, captured via on-robot recordings during an unsupervised four-week in-home deployment of an autonomous reading companion robot for children. We analyzed interviews and 160 interaction videos involving six families who regularly interacted with a robot for four weeks. Throughout these interactions, we observed how the robot's expressions facilitated unique interactions with the child, as well as how family members interacted with the robot. In conclusion, we discuss five design opportunities derived from our analysis of natural interactions in the wild.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in HCI*; • **Computer systems organization** → Robotics.

KEYWORDS

in-the-wild, social robots, in-home, child-robot interactions, reading

ACM Reference Format:
Joseph E Michaelis, Bengisu Cagiltay, Rabia Ibtasar, and Bilge Mutlu. 2023. "Off Script:" Design Opportunities Emerging from Long-Term Social Robot Interactions In-the-Wild. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI '23), March 13–16, 2023, Stockholm, Sweden.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3568162.3576978

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HRI '23, March 13–16, 2023, Stockholm, Sweden

ACM ISBN 978-1-4503-9964-7/23/03…$15.00
https://doi.org/10.1145/3568162.3576978

Figure 1: In-home child-robot reading interactions were designed as dyadic interactions with a companion robot, but we found instances of rich social engagement with multiple family members and off-script responses from children.

1 INTRODUCTION

Embedding robots in the real-world shows their performance in their intended roles, but also reveals *emergent* interactions with and around the robot. Studying these interactions provides insights into the *process* in which people adopt robots into their lives – how people wish to use robots, as opposed to what designers envision – and how the introduction of the robot changes the physical and social environment. For example, prior work has identified children bullying a shopping mall robot [41], factory workers chatting with a collaborative robot [49], and hotel customers engaging in *"heart-warming interactions"* with service robots [40]. These emergent interactions all point to new possibilities for interaction design.

We are interested in the emergent interactions of children and families with social robots within their homes. There is a major challenge in integrating these robots into the complex daily routines of families instead of disrupting their routines [9] so families feel they can accept and benefit from the robot [12, 21, 52]. Factors that challenge the integration of the robot into a family's life vary across family dynamics, routines, relationships [37], family values, expectations, parenting styles, and use of technology [1–3, 6].

Examining these aspects of long-term, in the wild studies in HRI, while challenging, are needed to produce invaluable insights into the user's needs and perspectives that emerge during real world interactions. To address this need, we conducted a study of child-robot interactions during a four-week in-home deployment of a learning companion robot designed to read with children. In an initial analysis of this deployment using interviews and interaction logs, we found that external factors such as family events or parental encouragement strongly influenced the child's overall experience with the robot and that children often modified their interactions over time to sustain engagement (See [6] for details on longitudinal changes to these interactions). In the current paper, we examine video records of interactions with children and families, from a camera onboard the robot, collected as part of this deployment. Our goal is to contribute an empirical account of families' unexpected and "off-script" interactions with the robot, and practical design implications that wouldn't have been possible to observe in a controlled lab study (See Fig. 1).

To meet this goal and make these contributions, we ask the research questions: *(1) What ways do children respond to robot actions during reading activities, and (2) How do families share the interaction space around the child-robot interactions?*

2 RELATED WORK

HRI In the Wild. Studying autonomous robots situated *in the wild* can uncover natural user interactions with a social robot in familiar and comfortable environments. Robots are studied in workplaces, campuses, museums, shopping malls, assisted living facilities, and homes [24, 29, 47]. However, the cost and reliability of a robot and the time and expenses of conducting field studies make in the wild studies challenging [22]. Jung and Hinds [22] recommends that HRI researchers should *"examine design elements in multiple different contexts,"* for example homes with different types of family structures, and *"explore a robot's influence on processes and dynamics of groups and the consequences of such influence."* Child-robot interactions are a prominent context for studying robots in the wild, since different family or group dynamics play a critical role and children can benefit from educational and social interactions at home, school, museums, or hospitals [16, 23, 38, 46, 50, 51].

Long Term HRI. Sustaining long-term use in these contexts is another pressing challenge for HRI [12, 23, 30, 50, 53, 55]. For example, in a long-term social robot deployment in schools most children lost interest in the robot over time [23]. Similar drop out rates were found in a 6-month deployment where some users expressed resistance, rejection, and discontinuation [10, 11, 45, 56]. One study, where Vector robots were deployed in homes for 6-months, found that personal attachment to the robot developed by 2-weeks but diminished after that [55]. These challenges to long-term use are associated with users feeling a lack of interesting functions, being disappointed in the capabilities over time (*e.g.,* speech), and families finding some of the behaviors annoying. To address these challenges researchers suggest designing more complex interactions [55] with multiple activity options [8], and meeting the social needs of users by building rapport through acting as a peer [28], providing self-disclosure through backstories and emotions [32] and incorporating past interactions into current activities [33]. Including a a fictional backstory and a capacity to express emotion through verbal and non-verbal channels [43, 48] may also support user's "suspension of disbelief" [13] to enhance these interactions. Some HRI theory observes how a robot's ability to simulate life can allow objectively fictional interactions to provoke genuine emotional responses, so long as the believability and coherence of the fictional backstories and conversations can be maintained to enable continued suspension of disbelief [14, 31]. Overall, more complex and multifaceted interaction design can lead to enriched mental models of the capabilities and social aptitude of robots [39, 54].

In-Home Child-Robot Interaction. There is limited research that focuses on the nuances of in-home robot interactions with children and their families. In-home robots for children are typically designed for educational, motivational, or socially assistive purposes, such as e-learning [16], reading assistance [36], or health coaching [25]. In over one-month in-home deployments, socially assistive robots have been found useful in delivering social interventions for children with autism (aged 3-7 [7] and 6-12 [50]). In a single interaction, Fink et al. [15] found that that a simple robotic box that used reactive behaviors helped motivate children to tidy up their toys, but that proactive robotic behaviors encouraged children to be playful and explorative. There is also some emerging evidence that family involvement in activities with in-home robot increases overall interaction [26]. A social robot that read to young children at home as its primary activity and included other simple interactions such as telling stories, playing music, and chatting with children appeared to successfully engage children over time in a long-term study. [57]. Overall, theory on in-home child-robot interactions is emerging, but typically focus only on the child, use short-term studies, or rely on self-report or log data rather than observation.

3 METHOD

3.1 Robot Interaction Design

We designed a reading companion robot for children to promote their interest in STEM reading and deployed this robot in homes. Children were provided reading supplies and were asked to regularly read to the robot at their own pace over four weeks[1]. In these activities, the robot frequently responded with social commentary to support the reading, was fully autonomous and engaged in one-on-one reading interactions with the child.

3.1.1 Robot & Equipment. We used the Misty II robot[44] due to its humanlike and compact design that made it suitable for an in-home deployment. Misty II has a 4-inch LCD display for a face, a chest light that emits LED colors, a mobile base, and head and arms that allow for body and head movements, facial expressions and gestures. The Misty robot platform is also equipped with four corner bumper sensors on its lower body. We programmed these bumper sensors to communicate specific actions to the robot. The *Repeat* bumper repeated the robot's most recent comment. The *Pause* bumper paused the reading interaction, allowing users to take a brief break up to 10 minutes. The *Yes/Continue* bumper allowed the user to confirm their actions or continue the interaction from the paused state. The *No/Quit* bumper allows the user to decline the robot's prompt or end the interaction. To support a longitudinal field deployment, we used a Raspberry PI 4 to handle the main computing power for the robot's interaction. We used a mobile hotspot to connect the robot and Raspberry PI 4 and provide a stable

[1]All resources provided in this study are shared for open access in OSF: https://osf.io/bks8w/?view_only=7664456907db4dfb8c44d56c1d1e2cfd

internet connection, which did not rely on participants' network connection. We used the mobile hotspot to also upload the collected data nightly and push program updates to fix and prevent errors.

3.1.2 Reading Supplies. The reading supplies included: 20 narrative-type informal STEM books, a reading journal, a tutorial booklet and informational "cheat sheets", topic cards used to rank the user's most and least favorite book topics, and volume control cards. The *reading journal* allowed the robot to identify who it was reading with by name, and was used for children to record their daily reading and express how they felt about each reading session. *Volume cards* allowed users to set the robot's audio level. Participants had access to a *tutorial booklet* describing and demonstrating the robot's functionalities. The *cheat sheets* had information about how to interact with and care for the Misty robot, answers to frequently asked questions, and how to travel with Misty.

All reading supplies were equipped with April Tags [42] used to identify the user through a tag placed on the journal, to understand which book is selected, which page is read, and for the robot to make a social commentary in response to the pages the user reads.

3.1.3 Social Commentary Design Process. Robot comments were written by the research team using an iterative process to create a realistic, peer-interaction experience where the robot's "character" was engaging, believable and friendly. Researchers wrote and reviewed audio of each comment for continuity and clarity, and adjusted prosody with Speech Synthesis Markup Language (SSML) using Google Text to Speech to create natural conversational intonation, pronunciation and timing. Based on prior research, we designed three types of comments, knowledge, social and interest supporting, for the robot to "say" during reading sessions.

Knowledge comments were created to support reading comprehension [20] and understanding the science content in each book [19]. We divided these comments into four categories, where the robot would use relevant information or clues from the text to make *predictions*, would *summarize* key information or complex sections, themes, and ideas, or rephrase difficult *vocabulary* words from the text along with a contextual definition. Finally, some comments were posed as *questions* to prompt short answers from children to activate their understanding and prior knowledge.

Social comments were designed to facilitate social connection-making between children and the robot for long-term interaction [30, 48] across four categories. Social comments included: *robot backstory* comments to self-disclose personal information and beliefs about the robot and help users identify the robot as a peer; comments that *recall* prior shared activities with the child such as previous books they have read with the robot; *personalization* comments that relate book content to children's topical interests; and, *emotional* response comments to express the emotional state of the robot through speech intonation and non-verbal cues such as facial expressions and changing colors on the robot's LED.

Interest comments were based on research connecting building value and a sense of belonging in STEM with interest development in these areas [17, 34]. We designed *value* comments to relate the theme of the books to something that would be of importance to the children, their families, or their communities. *Belongingness* comments made explicit connections to children's interests and abilities to what scientists do and scientific activities in the book.

3.1.4 Typical Interaction Flow. After the system boots, a bright blue headlight on the robot turns on indicating that the robot started video recording. During a *start-up phase*, the robot prompts the child to identify themselves by showing an ID tag on their journal, greets them by name, and expresses excitement to read with them. The child can choose to continue their most recently read book or choose any new book, where the robot suggests three new books based on their interests and reading ability. The robot then suggests a reading goal, that the child can accept or reject, of either the child's average reading time or a small increase to that time.

During the *reading phase*, children read the book aloud to the robot. Every 2-3 pages children will encounter a specially placed tag in the book that when shown to the robot will prompt the robot to "say" a knowledge, social or interest comment to relate to the text. Children continue reading, showing the tags, and listening to the robot's commentaries until they choose to quit reading. During reading, the robot passively indicates when the child reaches their reading goal by illuminating an LED on the robot's chest to a light purple. To end the reading phase the child presses the bumper sensor indicating "quit." If they attempt to end their reading before completing their reading goal the robot reminds them the remaining time and asks whether they would still like to end their reading. Once confirmed, the robot expresses a farewell and goes to "sleep." The video recording stops immediately after the robot expresses their farewell. At any time of the reading phase, users can also prompt the robot to repeat a comment or pause the interaction.

3.2 Participants

Sixteen families with children aged 10–12 were recruited via email lists from local community centers, university extension community programs, and faculty-staff lists. As part of the larger study goals, students were selected with low interest in science, based on a pre-study survey. In this paper, we focus on a subset of six families (five females, one male, mean age 11.3) to focus on our goal of characterizing unexpected or "off-script" interactions that might reveal novel interactions or imply opportunities for designing child-robot interactions. To meet this goal we selected a subset of families, prior to analysis, based on the following criteria. (1) To best characterize these "off-script" interactions, where activity beyond the child reading the book and robot making comments occurred, we chose families exhibiting a larger number of off-script interactions to maximize the number of instances of the phenomena to better characterize such interactions. (2) To minimize the impact of novelty effect on the off-script interactions, we chose families that exhibited a sustained level of reading across the four weeks. (3) To improve the breadth of possibilities for different types of family interaction, we selected varied family sizes. For demographic and reading sessions summaries, please see our open science project repository [5]. We refer to each child with the label C1–C6.

3.2.1 Consent Process and Ethical Review. Experimenters described the purpose, scope, and data collection methods to children and their parents, received verbal assent from children, and each parent signed a consent form to participate in the study. The research protocol was reviewed and approved by University of Wisconsin-Madison Institutional Review Board. Each family received $50 compensation at the end of the study.

3.3 Data Sources and Analysis Procedure

3.3.1 Data Sources. Data sources include semi structured interviews, interaction logs, and videos recorded from reading sessions. We conducted weekly online semi-structured *interviews* with families that focused on the child's and family's impressions and experiences with the robot. We collected interaction *logs* including date and time of the interaction, books read, reading duration, and a chronological list of events that occurred in the interaction (i.e., robot's speech, user inputs, system errors). We automatically collected *video recordings* of each session, from boot-up to shutdown, using a camera on the robot's head. Families were informed about when and how the video recording would be collected and consented to their videos being used as part of the research.

3.3.2 Analysis. We conducted a Reflexive Thematic Analysis [4] on video recordings of interviews (10-15 minutes each) and a total of 160 reading sessions (5-30 minutes each) from six participants. Researchers reviewed videos to familiarize themselves with the data, inductively generated semantic codes to construct more abstract latent codes, organized codes into categories, developed and revised candidate themes through discussion, and finalized themes through consensus. As emergent themes were the outcome, we did not conduct inter-rater reliability as described in Klein et al. [27] and Herrenkohl et al. [18], and recommended by McDonald et al. [35]. Throughout, when referring to the findings from video data we use the verbs "observed" or "heard" and when referring to quotes from interviews we use "they said" or "told us."

4 RESULTS

4.1 Theme 1: The robot's expressions promoted unique child-robot interactions

In observing how children interacted with the robot while reading, we noted that children were attentive readers, who commonly waved or said hello to the robot, would listen quietly to the robot, and often pause briefly before returning to their reading. On some occasions, they would apologize to the robot when they bumped it, and often spoke out loud to the robot when having difficulty in scanning tags. During the reading sessions we found that most visible responses to the robot occurred after the robot said a comment. These responses were most often after three types of robot comments, those designed to build their interest in STEM, those that infused the robot's fictional backstory into comments about the books, and those that included the robot's emotional displays with the comment. These three comment types were not specifically designed to elicit responses, and were only identified as prompting children to respond during this analysis. We found these responses to be consistent over time, including reactions to backstories and emotional social comments, where observations of interaction phenomena were distributed from beginning to end of participation. Below we describe how children responded to these comments.

4.1.1 Interest Development Comments Prompted Deflective Responses. We designed socially engaging interest comments to develop interest in STEM where the robot helped the child to make connections to scientists, engineers and mathematicians as well as STEM concepts and activities in the books. These comments either had the robot note how the STEM activity was important or valuable or how the child could be like the scientists, engineers or mathematicians in the books. Both of these interest development type comments received some responses from children, but those that suggested the child "*could be like the scientists*" seemed to be especially noteworthy to children. In interviews, these interest comments were often mentioned by three of the children (C1, C2, C6) who told us that these comments were "*encouraging*" (C6, C1) or "*nice*" (C2) and made them feel "*happy*" (C1) and "*confident*" (C2).

While interviews suggested children liked these comments, we often found children *deflected*, or seemed to disagree, with interest comments during the reading activity. As the robot made comments that connected what the child liked (*e.g.,* interested in art) to what was happening in the book (*e.g.,* scientists creating sketches) the children would often refute that connection. For example, during the book Math Inspectors, Misty says the calculation that the characters are doing "*is just simple multiplying and dividing. You are more than capable of doing that!*" In response, C6 became animated and said, "*Yeah. Not in me. Still not gonna happen. Not that smart.*" In this exchange, it appears that the child's quick response rejects the robot's suggestion that she could do the math in the book. However, in interviews, C6 later told us these types of interest comments were encouraging. C6 said the robot "*has a lot of optimism [in C6]... because she's always like 'I bet you could do that in the future'.*" In their last interview, C6 told us it was this optimism and encouragement that she would miss the most about the robot. C2 also encountered this same interest comment about being capable of doing the math in the book, but did not demonstrate any response during the reading session. However, later, during an interview, C2 referred to this comment to explain what it was like reading to the robot. C2 said, "*It makes me feel like she's a friend and she's being nice, and makes me feel like confident, I guess.*" When asked why, C2 told us, "*because sometimes she'll tell me like the kind of math they're using and that I would be able to do that.*" Similarly, C1 responded to a few of these interest comments during the reading activities as well, and again was deflective of Misty's suggestions. When Misty suggested, "*If you like to draw, just like these scientists, I think you have the potential to help others in the future,*" but C1 quickly responded by saying, "*I want to animate.*" Here we see how the child seemed to clarify Misty's assertion about liking to draw by sharing details of her own interest with the robot. This pattern also occurred in a similar exchange, where Misty suggested to C1 that she could be like the astronauts in the book, and C1 shrugged and said, "*I don't like space.*" Again, while deflective during the reading session, C1 later described these comments in a positive light. She told us she liked the comments, "*where she's [Misty] like 'oh, you could do this too when you grow up',... she will sometimes say, 'since you like art so much, you could easily help scientists out with this', so I definitely like that.*" Here C1 explicitly connected that the interests she shared at the beginning of the study was incorporated into this interest comment. This connection was explicitly designed, and C1's response seems to indicate that design was effective. When asked to interpret what the robot might mean by those comments, she said Misty was saying,"*'you have a chance to do this when you're older, you have a chance to help out the scientists', or like 'kids your age are doing stuff like this, you can too'.*" Here, we see evidence that these interest comments positively resonate with children, as the children brought up these comments on their own, but the longer-term impact may differ from what is initially observed.

Two other children responded to interest comments, again deflecting the comment, but did not mention these comments in their interviews. C3 seemed to have two sarcastic responses (based on tone of voice) to two interest development comments. C3 said an elongated "okay" in response to the robot suggesting she could do the math in the book. Additionally, when the robot said, "*I can see you making a mistake, and if you wanted to, still focusing on your goals because you are strong*," C3 said "*Oh, that's a nice compliment*," in a high pitched tone. C5 responded to one interest comment, "*Steve Irwin's love for wildlife grew from just working at his family's zoo. He then went on to become a naturalist. I can see you doing that.*" by saying, "*I hope I'm not getting stabbed to death by a stingray*," referring to the cause of Steve Irwin's tragic death in 2006. This response may indicate she did not like or feel comfortable with the connection made to this particular scientist. Neither of these children brought up interest comments in their interviews so it is difficult to say how they felt about them, but the interest comments did serve to prompt verbal replies from the children. Overall, while the interest comments delivered by the robot may seem to have little impact or to be dismissed by the child in the moment, there is evidence that these comments helped children feel encouraged and confident in their reading about science.

4.1.2 Children Imagined How Backstory Comments Could Have Happened. Another type of comment that elicited visible responses from children occurred when Misty would connect part of its fictional backstory to the book. The backstory comments were designed to build social connections, and involved Misty explaining how a section of the book reminded it of something that had (fictionally) happened to it in the past. The children's verbal responses to these comments often appeared to try and make sense of the robot having a backstory. For example, characters in one book hear of a friend being robbed, and Misty makes a backstory comment stating "*One time my neighbors got robbed and it was so scary!*" In response, C6 sat forward and said, "*Wait. Your neighbors got robbed. So, does that mean like a robot next to you in a robot station got taken to a family? Just saying. That would make you think they were robbed. Or if their charging station got taken away, that's a big rob.*" Here we see the child seeming to attempt to imagine how this event occurred to the robot. She seems to accept, or suspend her disbelief, that the robot is telling the truth and imagines what that must have been like. Two other children responded to backstory comments, where Misty refers to something "*in my house.*" The children seemed to have trouble believing that Misty has a house, where C1 responded by saying "*wait you have a house?*" and C3 appeared to sarcastically say "*Yeah. You have a house.*" Here we see that imagining the robot having its own home may have been difficult for the children, and this disbelief elicited a reflexive response. Overall, responses to backstory comments involved children grappling with the possibility and details of the event occurring.

4.1.3 Children Expressed Curiosity Towards Emotional Social Comments. Emotional social comments were the third type of comment that led to a noticeable response from the children. Misty was programmed to display emotion through changing facial images (*e.g.* eyes widening) and LED light colors (*e.g.* changing from white to dark blue). We found that three children (C4, C5 and C6) seemed to be most responsive to these emotional displays, where discovering and interpreting these emotions seemed to be exciting for them. They described emotions to family members and puzzled about what the displays meant. During interviews, when asked about what comments she liked, C4 twice referred to the emotions displayed during comments. C4 told us, "*I like that she can have on lots of different emotions when she says the comments*," and when asked about a comment he remembered from a new book, C4 told us, "*She [Misty] had a new emotion, she was nervous*," and included that "*she [Misty] turned purple*," and "*just looked really really worried*" in his understanding of that emotion. When we reviewed the video of this comment during the reading activity (See Fig. 2), we see C4 pause after the comment, move closer to the robot and look intently at the robot. C4 says, "*Um*," shifts his eyes across the robot and states, "*Worried.*" We see here that C4 spends time trying to understand the meaning behind the facial and light displays, and interprets the robot feeling worried within the context of the book. During the last interview, C4 said they "*like discovering the new emotions.*" C5 also seemed interested in interpreting the robot's emotional displays. When she first encounters a facial expression of emotion, the child pauses after the robot's comment and looks intently at the robot's face and then LED light, she pauses for a moment more and returns to reading. During another emotional social comment, Misty displays this same emotion to C5 during the comment. The child and her parent can both be heard laughing at the comment, and after a moment, the child explains to the parent, "*oh, by the way, her light changes when she has different emotions. Its blue when she's sad and so far I know it is yellow when she's curious.*" The mom asks, "*So what's this one?*" and C5 tells her "*yellow.*" C5 later told us in an interview that she "*liked the emotions that you got to see what the robot (felt).*" Again we see how the child spends time interpreting the emotional displays and seems to enjoy those parts of the robot's comments. For these children the emotional displays seemed to enhance their reading experience and spark their interest.

Figure 2: *Interaction illustrating Theme 1:* (a) the robot expresses "fear" as part of the comment; (b) the child is curious to understand the emotion associated with the comment; and (c) the child observes, comes closer, and says, *"Huh... worried."*

4.2 Theme 2: Spontaneous and enriching family interactions formed around the robot

We often observed and heard family members engaging in spontaneous and enriching interactions around the reading activities. Children sometimes shared their reading activities with the robot

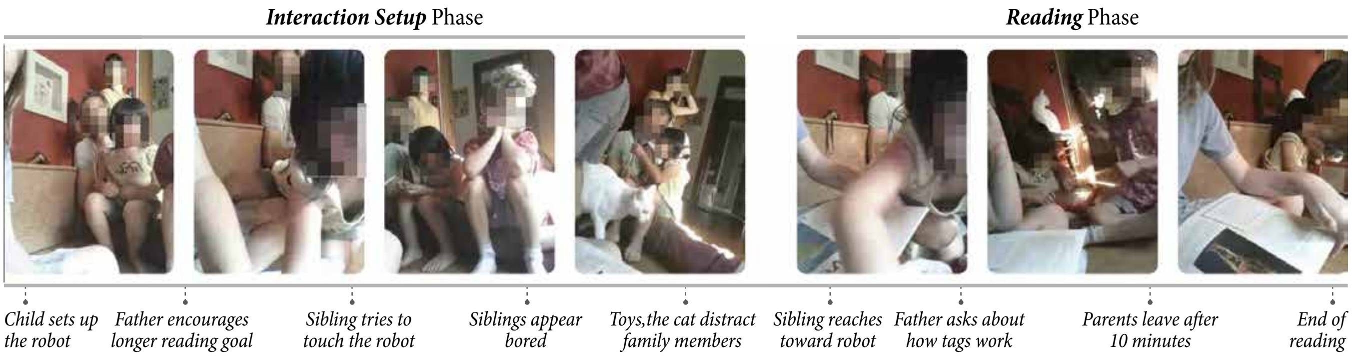

Figure 3: *Interaction illustrating Theme 2:* In this interaction, we see family members nearby engaging in spontaneous and enriching interactions around the reading activity with the robot. Design opportunities that focus on involving multiple family members emerged from such observations (*i.e., see Design Implications #4 and #5).*

with family members outside of their immediate family, but because these interactions involved individuals outside of the study, we do not report on them here. We did find that family members, especially parents, were often in the background, not visible to the camera, and could be heard interacting with their children, with help pronouncing a word, encouraging their reading, responding to robot comments themselves, or talking to their children about the content. Family members, typically siblings, also often sat in on readings and would sometimes interact with the robot. Below, we describe these as direct and indirect involvement in the reading.

4.2.1 Direct family involvement in the reading activity. The most direct form of family involvement with the reading activities was when one or more family members, typically a sibling, joined the activity. Of the three children with siblings, the younger siblings of C2 and C4 got involved, but C3's older sibling did not. Typically, C2 and C4's siblings would quietly but intently listen to the reading and the robot's comments, but other times they would play with toys or try to interact with the robot. The largest direct family gathering happened during week 3 when C4's mother, father, and two siblings sat with C4 during an entire reading session (See Fig. 3). All four family members watched intently during the beginning reading phase and added small engagements, including the father encouraging a longer reading goal and the younger sister attempting to press a button. As the reading session began, the scene was somewhat chaotic as both siblings moved to play with toys and the family cat runs through the room. When the robot makes its first comment, the younger sister jumps forward to listen and the father asks about how the tags work. The sister interjects at one point and makes a mistaken statement about the reading and C4 stops reading to correct her. Throughout the reading, C4 makes many pronunciation mistakes, but no one in the family offers a correction. C4's parents both leave after 10 minutes of listening. The siblings seem to vacillate between listening intently, playing with toys, and causing distractions, but stay near the reading activity throughout. Overall, the scene exemplifies how a family may take time for the activity, but need ways to interact to stay engaged.

C4's family was often involved in other reading sessions. At some points, his siblings would interject and ask about the robot. For example, the brother would often ask about details of the interactions such as ‘‘*What do these buttons do?*,” or “*Are you going to do 15 minutes again?*” C4 seemed to become accustomed to these interjections and would at times ask his siblings to wait for a response. When C4's brother interrupted one of Misty's comments, C4 waited for the robot to finish speaking before saying, “*What? What were you saying? Sorry I missed it because Misty was talking.*” On some occasions C4 would involve his siblings in pressing buttons to operate the robot, including selecting a book, finishing the reading session, and beginning a reading session. These interactions appeared to be distracting at times. On more than one occasion C4 asked the brother to leave because, “*I really have to read.*” Overall, the siblings were very interested in the robot and the reading and often asked to stay, where C4's sister liked to “*stay here until she [Misty] starts sleeping.*” Similarly, C2's younger sister joined two early reading sessions, and sat quietly and listened attentively while they read. During these reading sessions, we see the sister watch the robot and lean forward during comments, and she stays for about 5 minutes. With C4's family, the robot and the reading seemed to attract attention from siblings even though they are rarely directly engaging with the robot during reading. C2's younger sister also was attracted to the reading, but we note that she may have lost interest after a few early sessions. Here we see how young siblings attempted to make small engagement with the reading sessions but typically had little to do while there.

4.2.2 Indirect parent involvement in the reading activity. Other involvement from family members, in this case typically a parent, happened when the family member was nearby but not directly involved in the reading. Some parents would make comments about the reading goals that children chose when they overheard Misty setting reading goals with the child, or the parent would comment about the amount of time the child spent reading. Misty was programmed to remind the child of their usual reading time, and offer to increase their reading goal based on this time. We found that most children chose to stay with the lower reading goals and parents would sometimes verbally intervene. C5's parent was very involved in early reading sessions and helped C5 select higher reading goal times. During one of her earlier reading sessions, Misty suggested increasing their goal time, but the child chose a lower time instead.

When the robot confirmed by saying, "*Okay, let's try 11 minutes for our goal.*" C5's mom exclaimed, "*11 minutes!*" The child explained that's what they had normally read, and the parent then demonstrated their knowledge of the goal selection process by asking, "*Is that the lower one or the higher one?*" The parent then encouraged the child to choose the higher reading goal by saying, "*Why don't you do the higher one? Make it higher.*" The negotiation between parent and child continued during other interactions, including one instance at the end of a session where the robot asks if C5 should continue reading, and the mom, from the other room, loudly says, "*Yes.*" This parent influence around the reading goal impacts C5's later reading where she checks with her mother about a reading goal, and asks "*should I?*" when the robot suggests a higher reading goal. This type of influence occurred for other children, including C6, who when given a low reading goal of 7 minutes, C6's parent said, "*That's sad. No. You need to read longer.*" Sometimes minor interruptions to reading times around family schedules were visible as well, including C6, who was asked to take a break for lunch, and told the parent "*I'm just going to finish this chapter which will take just a couple pages.*" On another occasion C6 abruptly shut off the robot when the parent suggested they had to leave and the child could "*hit pause and finish it later.*" C4's family helped them track their reading time, and on one occasion might have reduced their time reading when they said, "*Sorry to interrupt you, but when you get to a good spot, stop, okay? Dinner is on the table.*" C4 also had a reading session interrupted by a crying sibling, where they abruptly discontinued their session. In these cases, we see how family influences can impact reading times and goals.

Another way that families got involved while not directly participating in the reading sessions were in reacting or talking about the reading content or the robot's comments. These reactions could be small. For example, on a few occasions the child and a family member, in the background, would laugh at something the robot said. On one occasion, C6 and her mom laughed when Misty commented, "*Whether it was a razor blade or a paper weight, it sounds like it hurt.*" This moment of laughter was spontaneous and seemed to be a shared moment between child and parent, where the child looked over their shoulder at the parent and the parent said, "*yeah it does.*" C4 and his parent both laughed at a comment where Misty says she wants to see the sparkles described in the story accompanied by widened eyes and a dream-like voice. The robot comments sometimes sparked a reaction from a parent, as when Misty explained that an MRI was a series of 2D images put together as one 3D image and C1's parent said, "*I didn't know that.*" C6 also received some vocabulary and pronunciation support from her parent who explained what a "glacial pace" meant and helped her sound out the word 'lichen' at two different points in the reading when C6 struggled to say the word. C5's mother helps C5 pronounce 'anemone' after C5 mispronounces it during reading, by sounding out the word for her. These interjections were short but demonstrate the way that the child-robot interactions can involve indirect family participation in the activity, such as vocabulary and pronunciation support.

Other more in-depth participation in the reading activities occurred as well. For example, C1 needed help pronouncing Temple Grandin's name, and the mother corrected the pronunciation while explaining "*she's an animal activist.*" Later C1 asked if Temple Grandin was still alive and the parent said, "*Yeah, she's still around. She actually was one of the people who got McDonald's to buy their meat for their burgers from more responsible farms, because the cows they were using to make their burgers had such horrible lives.*" C1 later told us in an interview that "*it inspired me to read more about [Temple Grandin] after that.*" In another example, C5 explained their own spontaneous connection to the content in a book to their parent. C5 read about how microplastics impact coral reefs, and told her parent standing in the background that, "*Microplastics is almost like coral junk food. When coral ingest microplastics and get a false sense of fullness which results in the coral not feeding on nutritious food.*" This comment seems to be a high level conceptual connection to the content of the reading, where the child shared their own knowledge in the context of their reading. Overall, in longer spontaneous interactions, the the indirect presence of the parent supplements or fosters the child's knowledge about the book.

5 DISCUSSION

In this paper, we asked two research questions. First, we asked, "*What ways do children respond to robot actions during reading activities?*" We found that children most often did not respond to robot comments, but some specific comment types seemed to elicit responses throughout the study. These responses included refuting comments designed to help them see personal connections with STEM, grappling with robot backstory comments to understand how they could have happened, and expressing curiosity about emotional displays while working to interpret the display's meaning. The stability of these "off-script" comments is in contrast to findings from another analysis of this research describing how interactions changed over time [6]. Second, we asked, "*How do families share the interaction space around the child-robot interactions?*" We found that when parents and siblings engaged in the reading interactions, parents where more often in the background and younger siblings joined near the robot. However, parents and siblings had limited opportunities to directly engage with the robot or activities.

5.1 Impacts and Design Implications

Here, we discuss the impacts and interpretations of these findings to examine how they connect and contribute to existing literature and their implications, including (1) the role of disbelief and incongruity in provoking visible responses, (2) how emotional displays can spark curiosity, and (3) how social robots can improve in-home interactions by designing for engaging other family members.

5.1.1 Disbelief and Incongruity. Visible responses from children may stem from feelings of disbelief or incongruity in interactions. When children refuted comments that connected them to STEM activities or grappled with understanding the possibility of the robot's backstory, their underlying sentiment may be disbelief. Perceptions of incongruity between interactions with the robot's fictional character and the child's beliefs about the world [14] may prompt a quick vocal response to indicate their disbelief. This disbelief may stem from an immediate refutation of words of encouragement from the robot that conflicts with how they see themselves, or inconsistencies with their conceptualization of the robot as fictional character and a particular aspect of the robot's fictional backstory may also provoke these responses. Thus, it may be difficult for children to continue their suspension of disbelief in these scenarios.

In examining children's responses to comments designed to influence their perceptions of and interest in STEM, we found that promoting a sense of belonging through robotic interactions can be effective. These interactions may appear to be received negatively or refuted in the moment, but emerge later in the child's recollection as positive support. In particular, some children noted it was encouraging for the robot to make specific connections between their expressed interests and the book content. This approach may be a useful technique for rapport building strategies that create long-term human-robot relationships [30, 33]. The complexity of these influences, where the effects may only show up later, may be a key part of the process, and warrants further investigation. Furthermore, backstory provided by the robot often elicited a response from children that focused on making sense of how that story could have taken place. This process seems similar to the process of suspending disbelief [14, 43] where the children know the backstory is not true but attempt to understand it as if it were true. Many of Misty's backstory comments, such as having a sibling, did not provoke a response, but some ideas, such as Misty having a house may have been inconsistent with the children's perception of the robot [14]. For example, C6 reasoned that Misty's "house" may have meant the store or space the robot was kept in. This response may indicate children will work to repair perceived inconsistencies in the fictional world of the robot. These findings point to the design implications below.

Design Implication # 1: Social robot interactions designed to draw connections between users and the interaction activity need to be precise to avoid deflection or feel disjointed. For example, in our study, we made connections based on a high-level knowledge of one child's love of art to connect to scientists in the reading who create sketches to illustrate problems. More precise knowledge of the types and mediums of art the child liked could have made this connection more believable or impactful to the child.

Design Implication #2: Backstories should be designed to create clear ways of making sense of them, where it is feasible for the robot to have done or felt such a thing and by being consistent with the physical attributes of the robot. For example, a robot with no arms could not lift a large object but might feel sad that it cannot.

5.1.2 Emotional Displays and Curiosity. Children's curiosity about the robot's emotions may stem from the reflexive nature of applying human social rules to non-human entities [54]. Children may look for meaning from changes in non-verbal displays by interpreting them in light of the current context or past interactions. Non-verbal emotional displays often sparked curiosity from the children. Understanding these displays were a challenging puzzle that some seemed to enjoy. Without a guide telling them exactly what each display meant, children worked to make inferences about each emotional display's meaning. Based on this finding, we infer:

Design Implication #3: Robot use of non-verbal cues should be designed to imply a variety of robot emotions, use multi-modal displays, and be open to interpretation by the user. Designing for emotions to be discovered can enhance interactions by creating a need to make meaning of the displays.

5.1.3 Engaging Family Members. Parents and younger siblings both seemed poised to join reading interactions in different ways. Parents more often stayed in the background and briefly interjected with their own knowledge and goal supports. Parents seemed to want to engage, but also be able to do other activities around the house. Younger siblings, appeared to want to directly engage and take part in the shared activity. Based on this finding, we infer:

Design Implication #4: Design for social robots to recognize others in the background, acknowledge their presence, and create multi-user modes that can include them in the activity. Robots might pause and shift attention while others talk, acknowledge the verbal contribution of others, or suggest changes to activity goals (*e.g.,* a longer reading goal). Multi-user interactions might be employed when others are detected. For example, the robot could acknowledge a sibling by name, and ask them a question about the activity, or ask if they would like a turn. Giving the main user options for multi-user modes in the interaction would increase opportunities to involve additional people in the interaction.

Design Implication #5: Design regular summary and preview reports as a means of connecting with parents, including activity reports, goal monitoring, and upcoming challenges (*e.g.,* difficult vocabulary). These summaries and previews might increase opportunities for background interaction when desired (*e.g.,* preparing for new vocabulary) or reduce the need for interaction (*e.g.,* not needing to monitor goals) when it is not.

5.2 Limitations & Future Work

This work was limited by several factors and will be bolstered by future work. First, we examined a limited number of families whose children engaged routinely with the robot. This decision was made to capture as many visible responses and family interactions as possible, but only provides evidence of the interaction process for children who demonstrated regular use of the robot activities. Future work, including future analysis of this data set, is needed to understand these interaction processes for children who discontinued use or whose interactions were limited. Second, these findings help shed light on early family and child interaction processes with a robot, but are not suited to make causal or generalizable claims about the effects of the interaction design. Therefore, future work is required to make these causal tests, by manipulating design conditions and exploring their effect on a larger sample of children and families. Finally, due to COVID restrictions, the study required no-contact delivery of the robots and resources, and interviews conducted over video calls. The lack of in-person contact between researchers and participants may have affected their participation.

6 CONCLUSION

Our work demonstrates the design opportunities that emerge from observing complex, dynamic, in-home and long-term human-robot interactions, including spontaneous and multiparty interactions that formed around the robot and reading activity. We believe these findings and design implications resulting from this work can better facilitate long-term in-home interactions by guiding designs that account for "off-script" family interactions.

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation (award #1906854 and #2202802). We would like to thank Jingyu Chen and Lisette Lurker for their support in coding the video data.

REFERENCES

[1] Erin Beneteau, Ashley Boone, Yuxing Wu, Julie A. Kientz, Jason Yip, and Alexis Hiniker. 2020. Parenting with Alexa: Exploring the Introduction of Smart Speakers on Family Dynamics. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[2] Erin Beneteau, Yini Guan, Olivia K. Richards, Mingrui Ray Zhang, Julie A. Kientz, Jason Yip, and Alexis Hiniker. 2020. Assumptions Checked: How Families Learn About and Use the Echo Dot. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4, 1 (2020), 1–23.

[3] Erin Beneteau, Olivia K. Richards, Mingrui Zhang, Julie A. Kientz, Jason Yip, and Alexis Hiniker. 2019. Communication breakdowns between families and Alexa. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.

[4] Virginia Braun and Victoria Clarke. 2022. *Thematic analysis: A practical guide.* SAGE Publications Ltd, London.

[5] Bengisu Cagiltay. 2022. STEMMates, Long-Term In-Home Reading Companion Robot Supplemental Resources. https://osf.io/bks8w/?view_only=7664456907db4dfb8c44d56c1d1e2cfd

[6] Bengisu Cagiltay, Nathan White, Rabia Ibtasar, Bilge Mutlu, and Joseph Michaelis. 2022. Understanding Factors that Shape Children's Long Term Engagement with an In-Home Learning Companion Robot. *ACM Interaction Design and Children* (2022).

[7] Caitlyn Clabaugh, Kartik Mahajan, Shomik Jain, Roxanna Pakkar, David Becerra, Zhonghao Shi, Eric Deng, Rhianna Lee, Gisele Ragusa, and Maja Matarić. 2019. Long-term personalization of an in-home socially assistive robot for children with autism spectrum disorders. *Frontiers in Robotics and AI* 6 (2019), 110.

[8] Alexandre Coninx, Paul Baxter, Elettra Oleari, Sara Bellini, Bert Bierman, O Henkemans, Lola Cañamero, Piero Cosi, Valentin Enescu, R Espinoza, et al. 2016. Towards long-term social child-robot interaction: using multi-activity switching to engage young users. *Journal of Human-Robot Interaction* (2016).

[9] Scott Davidoff, Min K. Lee, Charles Yiu, John Zimmerman, and Anind K. Dey. 2006. Principles of smart home control. In *International conference on ubiquitous computing*. Springer, 19–34.

[10] Maartje MA de Graaf, Somaya Ben Allouch, and Jan AGM van Dijk. 2016. Long-term evaluation of a social robot in real homes. *Interaction studies* 17, 3 (2016), 462–491.

[11] Maartje M. A. de Graaf, Somaya B. Allouch, and Jan A. G. M. van Dijk. 2017. Why do they refuse to use my robot?: Reasons for non-use derived from a long-term home study. In *2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 224–233.

[12] Maartje M. A. de Graaf, Somaya B. Allouch, and Jan A. G. M. van Dijk. 2019. Why would I use this in my home? A model of domestic social robot acceptance. *Human–Computer Interaction* 34, 2 (March 2019), 115–173.

[13] Brian R Duffy and Karolina Zawieska. 2012. Suspension of disbelief in social robotics. In *2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 484–489.

[14] Brian R. Duffy and Karolina Zawieska. 2012. Suspension of disbelief in social robotics. In *2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication*. 484–489. https://doi.org/10.1109/ROMAN.2012.6343798

[15] Julia Fink, Séverin Lemaignan, Pierre Dillenbourg, Philippe Rétornaz, Florian Vaussard, Alain Berthoud, Francesco Mondada, Florian Wille, and Karmen Franinović. 2014. Which robot behavior can motivate children to tidy up their toys? Design and Evaluation of "Ranger". In *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*. 439–446.

[16] Jeonghye Han, Miheon Jo, Sungju Park, and Sungho Kim. 2005. The educational use of home robots for children. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005*. IEEE, 378–383.

[17] Judith M. Harackiewicz, Yoi Tibbetts, Elizabeth Canning, and Janet S. Hyde. 2014. Harnessing Values to Promote Motivation In Education. *Advances in Motivation and Achievement: A Research Annual* 18 (2014).

[18] Leslie Rupert Herrenkohl and Lindsay Cornelius. 2013. Investigating Elementary Students' Scientific and Historical Argumentation. *Journal of the Learning Sciences* 22, 3 (July 2013), 413–461.

[19] William G. Holliday and Stephen D. Cain. 2012. Teaching Science Reading Comprehension: A Realistic, Research-Based Approach. In *Second International Handbook of Science Education*, Barry J. Fraser, Kenneth Tobin, and Campbell J. McRobbie (Eds.). Springer Netherlands, Dordrecht, 1405–1417.

[20] Gay Ivey and Karen Broaddus. 2000. Tailoring the Fit: Reading Instruction and Middle School Readers. *The Reading Teacher* 54, 1 (2000), 68–78.

[21] Eric W. Jensen, Sherman A. James, W. Thomas Boyce, and Sue A. Hartnett. 1983. The family routines inventory: Development and validation. *Social Science & Medicine* 17, 4 (1983), 201–211.

[22] Malte Jung and Pamela Hinds. 2018. Robots in the wild: A time for more robust theories of human-robot interaction. *ACM Transactions on Human-Robot Interaction (THRI)* 7, 1 (2018), 1–5.

[23] Takayuki Kanda, Rumi Sato, Naoki Saiwaki, and Hiroshi Ishiguro. 2007. A two-month field trial in an elementary school for long-term human–robot interaction. *IEEE Transactions on robotics* 23, 5 (2007), 962–971.

[24] Takayuki Kanda, Masahiro Shiomi, Zenta Miyashita, Hiroshi Ishiguro, and Norihiro Hagita. 2010. A communication robot in a shopping mall. *IEEE Transactions on Robotics* 26, 5 (2010), 897–913.

[25] Cory D Kidd and Cynthia Breazeal. 2008. Robots at home: Understanding long-term human-robot interaction. In *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 3230–3235.

[26] SunKyoung Kim, Masakazu Hirokawa, Atsushi Funahashi, and Kenji Suzuki. 2022. What Can We Do with a Robot for Family Playtime?. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction (HRI '22)*. IEEE Press, Sapporo, Hokkaido, Japan, 847–849.

[27] Maximilian Klein, Jinhao Zhao, Jiajun Ni, Isaac Johnson, Benjamin Mako Hill, and Haiyi Zhu. 2017. Quality Standards, Service Orientation, and Power in Airbnb and Couchsurfing. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW (Dec. 2017), 58:1–58:21.

[28] Jacqueline M. Kory-Westlund and Cynthia Breazeal. 2019. A Long-Term Study of Young Children's Rapport, Social Emulation, and Language Learning With a Peer-Like Robot Playmate in Preschool. *Frontiers in Robotics and AI* 6 (2019). https://www.frontiersin.org/articles/10.3389/frobt.2019.00081

[29] Min Kyung Lee, Sara Kiesler, Jodi Forlizzi, and Paul Rybski. 2012. Ripple effects of an embedded social agent: a field study of a social robot in the workplace. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 695–704.

[30] Iolanda Leite, Carlos Martinho, and Ana Paiva. 2013. Social robots for long-term interaction: A survey. *International Journal of Social Robotics* 5, 2 (2013), 291–308.

[31] James C. Lester and Brian A. Stone. 1997. Increasing believability in animated pedagogical agents. In *Proceedings of the first international conference on Autonomous agents*. Association for Computing Machinery, New York, NY, USA, 16–21. https://doi.org/10.1145/267658.269943

[32] Mike Ligthart, Mark. A. Neerincx, and Koen V. Hindriks. 2019. Getting Acquainted for a Long-Term Child-Robot Interaction. In *Social Robotics (Lecture Notes in Computer Science)*, Miguel A. Salichs, Shuzhi Sam Ge, Emilia Ivanova Barakova, John-John Cabibihan, Alan R. Wagner, Álvaro Castro-González, and Hongsheng He (Eds.). Springer International Publishing, Cham, 423–433. https://doi.org/10.1007/978-3-030-35888-4_39

[33] Mike E.U. Ligthart, Mark A. Neerincx, and Koen V. Hindriks. 2022. Memory-Based Personalization for Fostering a Long-Term Child-Robot Relationship. In *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, Sapporo, Japan, 80–89. https://doi.org/10.1109/HRI53351.2022.9889446

[34] Allison Master and Andrew N. Meltzoff. 2020. Cultural Stereotypes and Sense of Belonging Contribute to Gender Gaps in STEM. *International Journal of Gender, Science and Technology* 12, 1 (April 2020), 152–198. Number: 1.

[35] Nora McDonald, Sarita Schoenebeck, and Andrea Forte. 2019. Reliability and Inter-rater Reliability in Qualitative Research: Norms and Guidelines for CSCW and HCI Practice. *Proc. ACM Hum.-Comput. Interact.* 3, CSCW (Nov. 2019), 72:1–72:23.

[36] Joseph E Michaelis and Bilge Mutlu. 2018. Reading socially: Transforming the in-home reading experience with a learning-companion robot. *Science Robotics* 3, 21 (2018), eaat5999.

[37] David H. J. Morgan. 1996. *Family connections: An introduction to family studies.* Vol. 45. Polity Press Cambridge.

[38] Bilge Mutlu and Jodi Forlizzi. 2008. Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction. In *2008 3rd ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 287–294.

[39] Bilge Mutlu, Nicholas Roy, and Selma Šabanović. 2016. Cognitive human–robot interaction. *Springer handbook of robotics* (2016), 1907–1934.

[40] Junya Nakanishi, Itaru Kuramoto, Jun Baba, Kohei Ogawa, Yuichiro Yoshikawa, and Hiroshi Ishiguro. 2020. Continuous Hospitality with Social Robots at a hotel. *SN Applied Sciences* 2, 3 (2020), 1–13.

[41] Tatsuya Nomura, Takayuki Uratani, Takayuki Kanda, Kazutaka Matsumoto, Hiroyuki Kidokoro, Yoshitaka Suehiro, and Sachie Yamada. 2015. Why do children abuse robots?. In *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction extended abstracts*. 63–64.

[42] University of Michigan. 2022. April Tags. https://april.eecs.umich.edu/software/apriltag

[43] Ana Paiva, Iolanda Leite, and Tiago Ribeiro. 2014. Emotion Modeling for Social Robots. *The Oxford handbook of affective computing* (2014), 296.

[44] Misty II Robot. 2022. Misty Robotics. https://www.mistyrobotics.com

[45] Everett M Rogers. 2010. *Diffusion of innovations.* Simon and Schuster.

[46] Raquel Ros, Marco Nalin, Rachel Wood, Paul Baxter, Rosemarijn Looije, Yannis Demiris, Tony Belpaeme, Alessio Giusti, and Clara Pozzi. 2011. Child-robot interaction in the wild: advice to the aspiring experimenter. In *Proceedings of the 13th international conference on multimodal interfaces*. 335–342.

[47] Selma Sabanovic, Marek P Michalowski, and Reid Simmons. 2006. Robots in the wild: Observing human-robot social interaction outside the lab. In *9th IEEE International Workshop on Advanced Motion Control, 2006.* IEEE, 596–601.

[48] Magda Saraiva, Hande Ayanoğlu, and Beste Özcan. 2019. Emotional Design and Human-Robot Interaction. In *Emotional Design in Human-Robot Interaction.* Springer, 119–141.

[49] Allison Sauppé and Bilge Mutlu. 2015. The social impact of a robot co-worker in industrial settings. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems.* 3613–3622.

[50] Brian Scassellati, Laura Boccanfuso, Chien-Ming Huang, Marilena Mademtzi, Meiying Qin, Nicole Salomons, Pamela Ventola, and Frederick Shic. 2018. Improving social skills in children with ASD using a long-term, in-home social robot. *Science Robotics* 3, 21 (2018), eaat7544.

[51] Masahiro Shiomi, Takayuki Kanda, Hiroshi Ishiguro, and Norihiro Hagita. 2006. Interactive humanoid robots for a science museum. In *Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction.* 305–312.

[52] Mary Spagnola and Barbara H Fiese. 2007. Family routines and rituals: A context for development in the lives of young children. *Infants & young children* 20, 4 (2007), 284–299.

[53] JaYoung Sung, Henrik I Christensen, and Rebecca E Grinter. 2009. Robots in the wild: understanding long-term use. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction.* 45–52.

[54] Sam Thellman, Maartje de Graaf, and Tom Ziemke. 2022. Mental State Attribution to Robots: A Systematic Review of Conceptions, Methods, and Findings. *ACM Transactions on Human-Robot Interaction (THRI)* 11, 4 (2022), 1–51.

[55] Astrid Weiss, Anna Pillinger, and Christiana Tsiourti. 2021. Merely a Conventional 'Diffusion'Problem? On the Adoption Process of Anki Vector. In *2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN).* IEEE, 712–719.

[56] SM Wyatt, Graham Thomas, and Tiziana Terranova. 2002. They came, they surfed, they went back to the beach: Conceptualizing. *Virtual society* (2002), 23–40.

[57] Zhao Zhao and Rhonda McEwen. 2022. "Let's read a book together": A Long-term Study on the Usage of Pre-school Children with Their Home Companion Robot. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction (HRI '22).* IEEE Press, Sapporo, Hokkaido, Japan, 24–32.