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Understanding Design Preferences for Robots for Pain Management: A Co-Design Study

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***Abstract*: There is growing interest in psychological interventions using socially assistive robots to mitigate distress and pain in the pediatric population. This work seeks to address the deficit in understanding of what features and functionality young children and their parents desire to help with pain management by using co-design, a common approach to exploring participants' imaginations and gathering design requirements. To close this gap, we carried out a co-design workshop involving seven families (with children aged between 4-6 and their parents) to understand their expectations and design preferences for a robot designed for pain management in children. Data were collected from surveys, video and audio recordings, interviews, and field notes. We present the robot prototypes constructed during the workshops and derive several preferences of the children (e.g., zoomorphic shape, distractors and emotional expressions as behaviors). Additionally, we report methodological insights regarding the involvement of young children and their parents in the co-design process. Based on the findings of this co-design study, we discuss personalization as a possible design concept for future child-robot interaction development.**

Keywords—child-robot interaction; pain management; co-design; social robots; child; parent

I. Introduction

Pain is a subjective experience associated with complex, unpleasant feelings. By the definition of the International Association for the Study of Pain [1], it is "*an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*." Poor pain experiences in early life may lead to short-term consequences, e.g., extending the period of surgical recovery for the child [2], or even long-term consequences, e.g., developing chronic pain in later life [3]. Therefore, it is crucial to manage and minimize pain experienced by the pediatric population.

A variety of intervention approaches have been developed for helping children to cope with pain [4]. In addition to pharmacological intervention, several non-pharmacological treatments exist, including behavioral, cognitive, combined cognitive-behavioral, physical, and emotional approaches. One study [5] has highlighted some of these non-pharmacological interventions efficacious for relieving postoperative pain in school-age children, such as imagery, parental involvement, foot massage, positioning, play activities, and touch.

Socially assistive robots providing comfort, companionship, education, and therapy are a fast-growing subfield of human-robot interaction (HRI) [6]. Robots seem to work particularly well with younger children [7], given that pretend play and anthropomorphizing are related to children's abilities during this development period [6]. Some studies have explored the use of robots with children who are diagnosed with conditions such as diabetes [8]–[10], Autistic Spectrum Disorders [11]–[14], and intellectual disability [15]–[17]. There have been promising results of child-robot interaction (e.g., [21]–[24]) in healthcare experience and in particular in the case of pain management (e.g., [25]–[30]). However, so far, the decisions about designing robot applications have extensively been in the hands of robot designers [31]. It remains unclear what robot embodiment and behavioral HRI for pain management in young children (aged from 4 to 7 years old) should be considered from the perspective of young children themselves and their parents.

It is believed that the outcome can vary greatly depending on how children's technology is developed and who is involved in the process [31]. Co-design [33]–[36] is a common approach to explore the participants' imaginations and gather design requirements. Recent research into the use of social robots to improve children's healthcare experiences has proposed the use of co-design with children, parents/caregivers and healthcare professionals through interviews and focus groups [37]. We developed that idea of co-design study further by involving seven families (with children aged between 4-6 and their parents) in constructing a robot prototype at a co-design workshop. We aim to capture their ideas through the produced prototype artifacts and understand their design preferences for a robot designed for pain management in children.

Overall, the contributions of this paper include (1) a close investigation on young children aged 4-6 and their parents' design needs and preferences for a robot for pain management; (2) proposing design considerations for future research on robots for pain management in children; and (3) a step towards addressing the lack of involvement by young children in the development of robotic technology for that age group, with methodological insights for future related works.

II. RELATED WORKS

A. Robots for Pain Management

There is growing interest in psychological interventions using socially assistive robots to mitigate pediatric distress and pain. For example, a recent literature review [26] shows that humanoid robots (e.g., Nao, iRobi) and zoomorphic robots (e.g., PARO, AIBO, NeCoRo) have been used for alleviating pediatric pain from eight identified studies. This review argued that patient and family partners could contribute to a user-centered design that may lead to more effective interventions.

With respect to the embodiment of a robot for helping to relieve pain, one study [38] has explored the impact of virtual agents versus physical huggable robots on promoting socio-emotional interactions for pediatric patients aged between 3 to10 years old. The authors suggested that children who need a distraction from acute pain or ongoing procedures would benefit more from interacting with a virtual avatar, while a child who needs companionship may benefit more from a social robot.

Regarding behavioral HRI for pain management, a study [29] focused on using the Nao robot to provide cognitive-behavioral strategies (e.g., distraction and blowing) while children received a flu vaccination. Another study [27] compared empathy and distraction behavior using the IVEY robot to reduce pain in children during peripheral IV placement. This study reported that the empathy group had the lowest pain and distress scales and the distraction group had the highest. More specifically, one recent study [39] has used the Nao robot to assess pain and emotion in children (aged 4-15) undergoing procedural treatment by combining detections of children's facial expressions and voice quality.

B. Co-design Robots for and with Children

Various methods have been used to design social robots and explore children’s attitudes and perceptions of robots. One common approach is to study a target population's reaction to the robot [40], and another is to survey them about what they perceive and know about robots [41], [42] or ask them to draw a robot [43], [44]. Co-design for and with children [33]is another approach with a particular focus on tapping into children’s imaginations, enabling them to explore what essential features a robot should include, in various forms (e.g., drawing, sketch, prototype, discussion or presentation) from their point of view [45]. One early co-design study [33] has involved researchers and children (aged 7 and 11) in developing a storytelling robot. Another study [45] reported a co-design study with children (aged 6-11) to create a friend robot. A recent study [46] has engaged children (aged 7-11) to co-design a tutee robot in the classroom.

III. METHODOLOGY

As the first phases of our larger research on developing and evaluating robots for pain management in young children, the work presented in this paper aimed to elicit design needs and preferences for such a robot by conducting an exploratory co-design study. It has been argued that one challenge we are encountering in co-designing a social robot for children is the lack of consensus across child participants and the intergenerational participants [45]. To close this gap, we seek to give voice to these young children who are not yet well-represented in design studies of HRI and their parents by engaging them in the workshop on co-designing robots. Approval to perform the study was granted by the Ethics Committee of the Technology University of Eindhoven.

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A. Setup and Procedure

We organized three co-design workshops in October 2021. The workshop lasting about three hours (including two to three short breaks) contains the following four sessions:

- In this first session lasting about 20 minutes, the teacher facilitator introduced the design challenge of this workshop (i.e., designing a robot pal help communicate or relieve pain). An experienced teacher played the role of feeling pain while children needed to find ways to help her.
- In the second session lasting about 40 minutes, the researcher facilitator introduced zoomorphic robots such as MiRo-E and Pleo, a humanoid robot Nao, and a machine-like robot Zenbo Jr., as shown in Figure 2 to the child and parent participants. After this, children were encouraged to interact with these robots with some default and basic interactions such as moving, speaking, dancing, and facial and emotional expressions for around ten minutes in total.
- In the third session lasting about 40 minutes, children designed an ideal robot using available materials (Figure 3). Parents were present to help children build up their prototypes and record their child's ideas.
- In the final session lasting about 30 minutes, children first presented their design works one by one to the rest of the group. As a follow-up, the parent participants exchanged ideas about what they liked about children's design works and the potential impacts of such a robot.

Fig. 1. Co-design workshop with children and their parents to examine their design needs and preferences for a robot for pain management in children.

Fig. 2. From left to right, robots presented at our co-design workshop are MiRo-E, Nao, Pleo, and Zenbo Jr.

B. Participants in the Co-design Workshop

As shown in Table 1, we recruited a convenient sample of 7 young children participants and accompanying parents who were interested in participating in our co-design workshop. In addition to the child and parent participants, one teacher and one researcher were at this workshop to facilitate the process. Before the study started, the parents were asked to provide informed consent. We informed the participants and emphasized to the child participants that they did not have to answer any questions they didn't want to. We gave children and their parents the right to stop participating in the study at any time they saw fit.

TABLE I. PARTICIPANT FAMILY DEMOGRAPHIC

Family ID	Family demographic background		
	Parent (Age)	*Child (Age)*	*Previous robot experience**
1	Father (35)	Boy (4)	No
2	Father (33)	Boy (4)	No
3	Mother (36)	Boy (4)	No
4	Father (44)	Boy (6)	A robot-alike play toy
5	Mother (37)	Girl (6)	Pleo
6	Father (38)	Boy (6)	No
7	Father (42)	Girl (5)	No

* Whether or not the parent and child have had already interacted with any robots before this study.

C. Materials for the Co-design Workshop

It is challenging to imagine and design future technologies, especially for young children without extensive robotic knowledge and with limited drawing skills. Inspired by the Robo2Box [47], a toolkit designed to elicit children's design requirements for classroom robots, we developed a similar construction toolkit containing a series of easy-to-use supplies (Figure 3) for participants to construct their ideal robot prototypes and enable them to broaden their design views. Similar to Robo2Box, our construction toolkit contains torsos, heads, legs, arms and decorative materials, which can be categorized as human, animal or machine-like. Additionally, our work extended the Robo2Box by adding one more design element of interactive attachments enabling children to ideate and create possible robot behaviors and interactions.

Fig. 3. Examples of the construction toolkit and materials at our co-design workshop for building up a robot prototype: (a) varied shapes of **torsos** [top], varied hard **materials** [bottom]; (b)varied shapes of **heads**, **legs**, and **arms**; (c) varied soft **materials**; and (d) mock-up **interactive attachments,** e.g., cameras, speakers, interaction sensor.

D. Data Collection

Data were collected from surveys, interviews, video and audio recordings, and field notes. Before the workshop started, we collected participating families' demographic information (Table 1). During the workshop, two cameras and voice recorders were used to record the children's verbal expressions about their designs and ideas and the visuals of children's design works. One-on-one interviews lasting around fifteen minutes were conducted with the participating parents immediately after the workshop to ask further questions regarding their ideas about a robot for pain management and their child's design work.

IV. RESULTS AND DISCUSSION

A. Children's design preferences and possible design considerations for future research

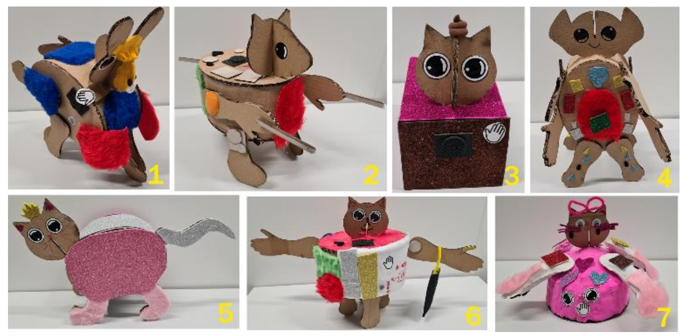

Fig. 4. Examples of the children's robot design prototypes. (Note: numbers on each picture indicate the participating children's registered ID; see Table 1 for cross-reference)

As shown in Figure 4, children's robot prototypes from the co-design workshop demonstrated interesting patterns. **First, all children, to different extents, included in their ideal robots animal-like appearance or features**. Three children (C3, 5, 7) explicitly presented their ideal robot as a cat robot while C2 created a dog robot and C1 designed a combination of rabbits, octopus and pony-like robot. Interestingly, C6 expressed that his robot would look like a combination of cat and human, move like a dog, and make sounds like a dinosaur. Similarly, C4 mentioned his ideal robot would look like a dog but move like a human. These results suggested **an apparent propensity of children to like zoomorphic robots**. This result aligns with previous research [48] that children interacted with robots like pets, but might be influenced by the following two aspects: (a) the examples of zoomorphic MiRo-E and Pleo robots shown at the introduction session, and (b) the provided toolkit contained mainly organic shapes that can be identified as parts of human or animal bodies. Future work may consider comparing the effect of pain management in children among different type of appearance of robot while controlling their functions. Some early studies [29], [39], [49]–[51] have applied humanoid robots such as Nao for pain management. Our findings indicated that zoomorphic robots should be further explored in children's pain management. Future research may investigate how zoomorphic robots extend the possibilities of animal-assisted therapy for relieving children's pain [52] and apply on a larger scale.

We also found **that children favored various interactive features and behaviors** that can be related to emotional to behavioral-cognitive strategies for pain intervention. Several children mentioned that they want to have **playful distractions**, such as playing games (C6), playing with tangible interactive buttons (C4), singing and dancing with the robot (C7), and spraying ice, water or bubbles (C5). Besides, some children favored the **rewarding or comforting behaviors by** the robot **providing their favorite toys and foods**. C3 wanted the robot to "shoot toys" for sick kids, while C4 envisioned storing toy-related tools for him. Two other children designed a robot feature for storing candy (C1) or food (C6).

Interestingly, some children choose robot behaviors, which reflected **routine activities with their parents or someone close to them**. For instance, C5 wished the robot to clean up for her when she was unwell, and her mother commented that this is something she would ask C5 to do herself at home. Similarly, C7 envisioned her ideal robot would read stories and comfort her when unwell. In a follow-up interview with her dad, we found that these behaviors were precisely how her parents and teacher would usually deal with her discomfort. Last, **self-expression and emotional support** seemed to be favored by children as well. For instance, C6 stated he wanted to express his emotions to the robot by pressing different colored buttons. Mutual emotional expressions between the robot and the child patient are essential. On the one hand, one work [53] on robot trainers for rehabilitation therapy pointed out that allowing the robot to perceive and respond to a patient's emotional condition can improve their experiences. On the other hand, a recent study on child-robot interaction in the pediatric context [21] has found that children express pain and anxiety differently. Our study also indicated that enabling children's emotional expression to be recognized by the robot and providing timely support is an important concept in robotic applications for pain management.

Our findings regarding children's choice of different robot behaviors suggest that **personalization** could be an essential design guideline that future work should consider. This is also in line with previous advocacy stating an intervention is most efficacious if it is tailored to children's preferred coping styles [4], [54]. Research has shown that children have individual preferences for dealing with painful medical procedures [4]. Some children likely prefer distractors, i.e., to be engaged in other tasks, while others prefer receiving information about the possible pain levels before the procedure. Future work may focus on establishing a child profile during the early interactions with the robot and providing personalized behaviors in the follow-up interactions. Based on the outcomes of this study, we suggest additional ways to achieve personalization in child-robot interaction such as (a) personalization of the robot's appearance, e.g., dressing up the robot using a set of accessories and using chosen materials; (b) a robot's persona, e.g., giving the robot a name, gender, role, personality and behavior style; and (c) a robot's interaction-modality personalization, e.g., adding touch-based interaction wearables or buttons to the robot.

B. Parents' perceptions on a robot for pain management and roles in the co-creation

Our interview results show that there was indeed some consensus regarding design ideas for robots between parents and children. P3 explained her child's (C3) favorite behavior of storing candy and further commented, "*I think it is a very good idea. I think I can also have a similar design as the kid makes it like a blind box.*"

Parents (P1, P2, P4, P6) mentioned children tend to focus more on the playful aspects while parents focus more on the functional aspects of HRI. For example, P1 explained he prefer to have the robot as a toy with voice interaction than C1's idea (the robot has lots of hands like octopus and the function of storing candies. In addition to his child's idea of this funny feature, P6 expressed his preferred functions of emotional support "*They (robots) should provide some emotional care, [..]. I think that's the important part […],I think cell phone already has a lot of stuff that can distract the children. You can play YouTube, and maybe it also helps. I think the robot should do more than these.*" This **difference in playful versus function-centered perspective** confirmed our expectations that involving children and their parents in developing such a robot is meaningful as this would help us find more diverse perspectives.

In addition, **parents' involvement in the co-creation exhibited different levels of help to their children**. For example, some (P1-2, 4) mentioned they were involved as an **observer,** and they enjoyed watching how their children reacted to this design challenge. Some (P3, 5-7) perceived themselves as the **executor** doing what their children asked them to do. In some situations, they acted as a **helper** for the children when they knew a specific question (P1) or handled a complicated tool like gluing the prototype (P2, 6-7). Some parents were involved as a **co-designer** (P2) or a partner giving feedback (P3-4) to their children, in a particular situation just as P2 mentioned, "*Maybe also co-designer. Sometimes he wants me to put something at a place, […] I can tell him that it's not easy to put there, or it can be broken very easily, then we can adjust the design together*." This finding extends the view that the patients and family members can contribute to the design of HRI [26] and demonstrates its added value for working with young children and their parents. We would suggest future research working with children at that age may consider involving their parents in the co-creation and giving the parents a flexible role to, e.g., record children's ideas, help complicated tools or provide feedback.

V. Conclusion

We engaged seven child-parent pairs in a co-design workshop to understand the preferences of young children for a robot design that is suitable for pain management. Our findings indicate children's preference for the zoomorphic shape of the robot and robot behaviors/interactions as a playful distraction, emotional expression, etc. Based on this study's findings, we suggest that future research focus on HRI personalization to make the robot-based intervention on pain management more pleasant and potentially more successful. Also, we conclude that co-designing with children aged 4-6 can produce valuable insights, and the combined involvement of parents can contribute to the children's robotic technology development.

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