Design of Child-robot Interactions for Comfort and Distraction from Post-operative Pain and Distress

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ABSTRACT

There are numerous strategies for reducing the stress and anxiety associated with pain that children experience before and after surgery. There is a potential communication barrier between hospital staff and the child which may result in inadequate pain management. Social robots may reduce the gap between the support that personnel can provide and what the children's emotional needs are. This study qualitatively evaluates the interactions between children and their parents who interact with the social robot MiRo-E. In the overall interaction, the robot would act like a pet and show different behaviours based on the estimated pain level of the children. However, in the current study, only the quality of the robot interaction behaviours was tested with healthy children and no pain was measured. During this study, two usability tests were done. Each usability test evaluated a different robot interaction. In both tests, children and their parents evaluated the designed interactions. Results indicate that children initially have different responses to the robot. They can either be held back from immediately interacting or they are not afraid of the robot at all and start touching it and interacting immediately. Although the intended behaviours could be more elaborate and personalized, both children and their parents appeared to like the different emotions shown by the robot and how it responded to their touch. The parents also offered some ideas to enhance the interaction between a child and a robot in a medical context, such as by including more sounds, making some behaviours more distinct, and allowing kids to customize the robot's look.

CCS CONCEPTS

• Human-centered computing→ Human computer interaction (HCI)→ HCI design and evaluation methods~Usability testing

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

ACM ISBN 978-1-4503-9970-8/23/03.
https://doi.org/10.1145/3568294.3580174

KEYWORDS

Child-robot interaction, robots in healthcare, pain management for children

ACM Reference format:

Oriana Isabella Ferrari, Feiran Zhang, Ayrton A. Braam, Jules A.M. Van Gurp, Frank Broz, and Emilia I. Barakova. 2023. Design of Child-robot Interactions for Comfort and Distraction from Post-operative Pain and Distress. In *the Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI '23 Companion), March 13-16, 2023, Stockholm, Sweden.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3568294.3580174

1 INTRODUCTION

Children who undergo minimally invasive surgery in a hospital often experience pain that is exacerbated by negative emotional experiences [1]. anxiety, fear, and stress are common emotions in children who need to be operated on, as well as their parents. These negative emotions can worsen their pain perception and delay their recovery [2]. Therefore, it is critical to manage the pain of children who must undergo surgery.

There are several interventions available to help children cope with pain [3]. In addition to pharmacological treatments, a variety of non-pharmacological therapies, such as cognitive-behavioral, physical, and emotional strategies, can be used in hospital pain management. We investigate whether social robots could be a part of such an intervention. Robots have proven to be effective tools to promote engagement and reduce stress for children [4],[29] [28]. They may be able to connect with kids who are less responsive to conventional human interactions [6] since they can be designed to sustain engagement by boosting motivation and assisting in monitoring, coaching, and communicating [5][29]. We expect that child-robot interactions can be designed to bring better communication between hospital staff and the child about their pain-related experiences.

The theoretical background and related work will be summarized first in this paper. Following that, the designed robot interactions will be described, and tested. The results of the usability pilots will then be discussed. Suggestions for future work will be offered at the end.

2 THEORETICAL BACKGROUND

2.1 Postoperative Pain Management

Experiencing pain as a young person can have short-term and long-term consequences. The recovery period of the child can be extended [8] or they can, later in life, develop chronic pain [9]. It is thus important to manage the pain that is experienced postoperatively by children.

There are several ways to minimize the discomfort that children experience following surgery. For school-aged children and adolescents non-pharmacological therapies, such as cognitive-behavioural strategies (e.g., guided imagery, play activities), physical methods (e.g., foot massages), and emotional ways (e.g., caressing the forehead, skin above wound) have been proven to be effective [10][3].

It is difficult for adults to be able to assess whether a child is in pain after undergoing minor surgery. This prevents optimal pain management postoperatively [11]. Communication difficulties make it difficult for nurses to appropriately estimate children's pain [12]. Figuring out the emotional needs of children is thus a very difficult task for the healthcare team. Over the years, different methods have been employed to coax the child to self-report their level of pain. The use of “face scales” is one of the most popular methods [13], but even using this method the children have trouble telling adults how much pain they are experiencing.

2.2 Target Group

Young children experience a lot of stress before, during, and after their hospitalization. The parents of the children have a significant impact on how stressed they are. Because parents are physiologically linked to keeping their children safe, it is believed that their absence from the hospital causes the youngsters stress [14][15]. The support and comfort of a parent are thus very important when a child has to be operated on, but the stress or anxiety felt by a parent can also make the child feel stressed or anxious [16][17]. Another stressor for the children is the unfamiliarity in the hospital setting. They do not know what they will encounter regarding the location and people [18]. Lastly, the children often do not understand why they have to undergo surgery. This can lead to them seeing their stay in the hospital as a punishment, which adds to their stress and anxiety levels [14].

3 RELATED WORK

3.1 Pain Assessment

When patients are not properly able to communicate their feelings to their caregivers, it is important to be able to measure their level of discomfort or pain. Self-reports and observations may not be accurate enough to help the patient manage their pain. The research of Frederiks and colleagues [19] used a sensor sock in a study to see what the effects of a bio-response system has on the communication between patients with limited communication skills and caregivers.

3.2 Distraction From Pain

Several studies have been conducted to determine whether distracting a child during a painful event, such as surgery, can reduce their pain perception. For example, James et al. [20] found that animated cartoons could be used to reduce pain perception in children before, during, and after a venepuncture procedure. When the results of having an active distraction (electronic gaming), passive distraction (watching television), or no distraction when one must put their hand in cold water for as long as they could tolerate were compared, the active distraction increased the participants' pain tolerance [21]. Participants who had an active distraction experienced less anxiety than those who had no distraction or a passive distraction. A virtual reality distraction system has also been tested on dental patients to see how it affects their anxiety and pain levels [22]. The participants experienced less anxiety and pain when distracted, according to both physiological data and self-evaluation.

3.3 Social Robots and Pain Management

Research on how social robots can be implemented in the healthcare sector is becoming increasingly available. Yasemin et al. [23] conducted a study to determine whether a robot can help reduce dental anxiety and pain in children. To assess dental fear and anxiety, they used the Facial Image Scale [13] in the form of a questionnaire. They compared two scenarios: one with and one without the assistance of the robot. This study found that robots could provide better social and emotional support to children during dental procedures than traditional intervention techniques.

Logan et al. [4] investigated whether introducing a social robot into a paediatric hospital setting was feasible and acceptable. Children aged three to ten were asked whether they preferred a plush teddy bear, an interactive social robot teddy bear, or a tablet-based avatar version of the bear. The results show that the social robot had a greater positive effect than the plush animal. Interactions with the robot were also perceived as more pleasurable and agreeable than the other two interventions. Logan, et al. [4] conclude, that the social robot that the social robot could help meet the emotional needs of children receiving medical care.

4 INTERACTION DESIGN

4.1 The MiRo-E Social Robot

MiRo-E is an animal-like robot (Figure 1). The appearance is a hybrid of several animals, including a rabbit, a dog, and a goat. The MiRo-E robot can be used in a variety of settings, including universities, schools, hospitals, and nursing homes [25]. Our goal is to employ Miro-E to entertain and emotionally engage the user by utilizing its six senses which provide natural behaviours and interactions. Moving, feeling, thinking, observing, speaking, and hearing are the six senses implemented in the robot.

Figure 2: Participant Interacting with MiRo-E Robot

4.2 The Interactions

The robot can be used in a variety of settings throughout the hospital. The robot should first be present during the pre-operative evaluation, then accompany the child during their time in the DCS, be placed on the bed while the child is moving between locations, and finally, be in the recovery room when the child awakens from anaesthesia. Multiple patients may be present in both the DCS and the recovery room. To ensure that MiRo-E keeps close to the designated child, the range of movement has been limited to stay close enough to the bed of the child, and the child determines when and how to interact with the robot. An adult should be present while the child uses the robot to ensure its safety. This can either be a parent or a medical professional.

The main objective of the robot is to distract the child from their stress and anxiety while they are in the hospital. The robot attempts to attract the child's attention by moving around the child's bed and expressing various emotions. MiRo-E responds to the kids' interactions by changing emotions when touched and dancing when one of the cube's sides is shown. The robot will be the child's hospital companion and will provide comfort when they are in pain. When the child no longer wishes to interact with the robot, it will fall asleep until touched again. As a result, the child has control over when and how long they interact with the robot.

5 USABILITY PILOT TESTS

5.1 Method

Two usability pilot tests were carried out in order to design the robot's behaviours and interactions. The pilots were designed to (1) test how a child would interact with the robot, (2) collect feedback on the designed interactions, and (3) solicit ideas on how to improve the robot and experience. These pilot tests were conducted to determine how children would interact with a social robot in a familiar setting with no external distractions in order to form a baseline conclusion on the interactions themselves. An identical setup was used for both pilots, but the interactions of the second pilot were different because they were re-designed versions, based on feedback from the first pilot. Also, different parent-child couples were involved in the second pilot.

The initially designed behaviours were tested in the first pilot and fine-tuned for the second one. Three simple interactions occurred: comfort-seeking, happiness, and dancing. The setup of the second pilot test will be the focus of this paper. The behaviours of the robot and interactions with the children for the second test are shown in Figure 2 and explained in Table 1. In this table, the different emotions are stated in the first column. The second column depicts the robot behaviours corresponding to the emotion listed in the first column, and the third and the fourth column depict the interaction behaviours triggered either by the robot or by the child.

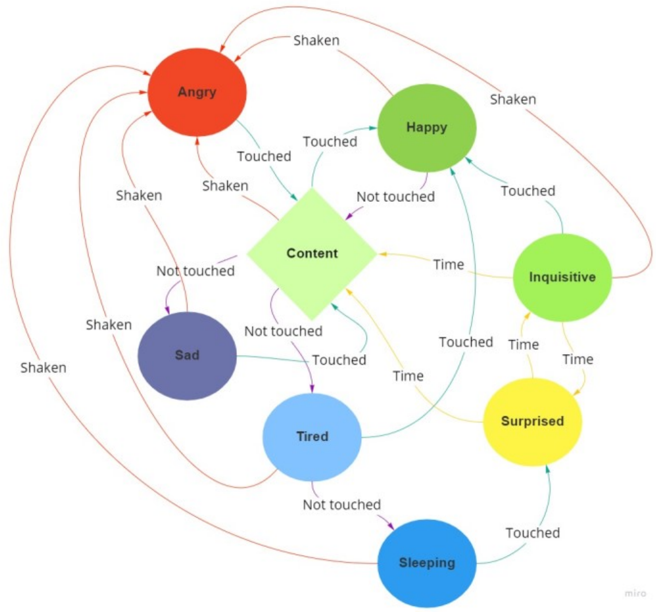

Figure 3: State diagram of the responses of MiRo-E to child initiations.

Emotion	Posture and lights on body	Movement of robot	Interaction trigger by a human
Content	Eyelids nearly closed, darker shade of green lights. Slow movements around the space	Slowly drives around, bob head gently, slight rhythmic tail wagging, cooing sounds	Petting by a person makes it content/happy
Happy	Rainbow of colours moving around, similar to content but more energetic.	Drives around at a faster speed, chirping noises, tail wagging quickly.	Petting by a person makes it content/happy
Sad	Lowered head, eyes nearly closed. Blue colour. Ears turned outwards. Tail down.	Slow blinking, sad noises. Tries to spot a person by head movements	Not touched for a short time
Tired	Stops moving, eyelids almost closed	Eyelids closing slowly, head slow movement down.	Not touched for a long time

Sleeping	Eyes closed, no wheel movements	Rhythmic breathing behaviour, no or snoring sounds	Not touched when tired
Angry	Red lights, ears facing back, tail up stationary	Ears small twitchy movements	Walk away from person; angry when shaken
Surprised	Eyes wide open. The head raised. Ears facing front. Colour yellow.	Stand still in the described posture (deer in headlight)	Touched when sleeping

Table 1: The improved interactions between robot and child after the insights of the first pilot.

A total of five children and three mothers participated in the second pilot study (Table 3). Two of the children, C2 and C5, fell outside of the age range, but the decision was made to include them in the study to gain more qualitative insights.

	Parent	First child	Second child
1	F1	C1: 6 years old, male	
2	F2	C2: 8 years old, male	C3: 6 years old, female
3	F3	C4: 5 years old, female	C5: 3 years old, male

Table 2: Participants second pilot

5.2 Results

The robot and its designed behaviours seemed to please both the children and the mothers. Three out of five children did not require parental encouragement to begin interacting. The children especially enjoyed playing and dancing with the QR-cube interaction, but they also enjoyed the various emotions and their triggers. Even if they could not always verbalize their emotions right away, they knew how to respond to them and recognize them later.

The parents liked the robot's playful interactive (trigger-action) behaviours. The following enhancements were suggested by the parents: (1) adding more sounds; (2) increasing the difference between specific emotions; and (3) allowing the kids to customize the robot. They also suggested that the robot might be an excellent substitute for a pet in a hospital setting because it would keep the child occupied and be more effective at establishing a rapport than the professionals.

6 DISCUSSION

We designed, implemented, and tested a variety of interactions to determine how the robot-child interaction should occur in order to distract and comfort children. These interactions were tested with healthy children and their parents in order to gain qualitative feedback on how to enhance the behaviours and interactions. The final design is described in Table 1 and Figure 2 and can be used in related research.

The majority of participants in the tests stated that the robot's appearance is endearing because it resembles a cute robot pet. Children should be able to customize the appearance of the MiRo-E to match their personal coping style [3][28]. This would be a good addition to the future development of this project.

The target group of hospitalized children in postoperative care, as defined at the beginning of this paper, was not involved yet. As a result, it is unknown whether the designed behaviours are complete and adequate for assisting children in managing their stress and pain. The robot and its interactions are currently being tested with children in the hospital.

The main findings are that more playful interaction options, such as the QR cube with dances, should be included to make interacting with the robot more enjoyable and fascinating. Furthermore, the second pilot test revealed that the robot should make more noises to communicate its emotions, or even be able to converse with the children. Future steps should consider how to incorporate elements like improved emotions, playful elements, and sounds. Furthermore, we recommend looking into accessories that meet children's needs while also adhering to hygiene standards and not interfering with the robot's sensors. This could be accomplished by using small items such as washable ribbons for the ears and different coloured collars, or by allowing the child to add their favourite stickers that can be removed at the end of the day.

7 CONCLUSION

The project's overall goal was to develop an easy-to-use interaction with a social robot that provides comfort and distraction for children who are in pain or distress after surgery. The current study only investigated the comfort and engagement of healthy children, and their ability to recognize the expressed emotions of the robot and seemingly interact with it.

As a main result, emotion-expressing behaviours and autonomous interactions for the MiRo-E robot have been developed (Table 1, Fig. 2) and validated. The interaction can be initiated by either the robot or the child. The pilot test revealed that children respond appropriately to robot interaction initiations. A QR cube with a different song and dance triggered by each side of the cube is used to add more playful elements. The robot invited the kids to interact with it by changing its emotions based on how the kids interacted with it.

Further research in a clinical environment is ongoing. This is needed to determine whether the designed behaviours are helpful and complete enough for pain management and stress relief of children who are in pain.

ACKNOWLEDGMENTS

I would like to thank all the families who took part in both usability tests. I would also like to thank Prof. Ignacio Malagon from Radboud University Medical Center for guiding the process from a medical standpoint, providing advice and feedback from the hospital's perspective, and providing the opportunity to test the designed interactions in the hospital.

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