Robots for pain management in children

Introduction

This project aims to develop technological solutions that include wearables for measuring physiological signals related to detection and fear of pain and child-robot interactions that can comfort the children or help further understand the pain experience of the child. Machine learning algorithms are being developed for both pain detection and selecting adequate robot behaviors.

Reducing children's suffering from pain or fear of pain with non-pharmacological interventions can have many benefits such as pain distraction, self-exploration of pain, and explanation of predicted severity of pain. The technological solution with the involvement of a social robot is developed to explore and further shape these possibilities.

The project integrated the expertise and strengthened the ongoing collaborations between Eindhoven University of Technology and Radboud university medical center, VU University Amsterdam, Twente University, and the Technical University of Delft. Four senior researchers and young researchers (a recently graduated postdoctoral fellow, three graduate students (two master's level and one bachelor level) were involved in the current project. The collaboration was extended to also include a young and innovative small company called BMD Studio, to ensure that the technology can be reused and updated even after the young researchers working on the project peruse new career opportunities.

The project went through several phases.

Phase 1 Defining requirements

This phase aimed to understand what kind of behavior and appearance of a robot for pain management will appeal to young children and their parents. Co-design method, a common approach to exploring participants' imagination and gathering design requirements was carried out including seven families (children aged between 4-6 years and their parents) to understand their expectations and design preferences for a robot for pain management. Data were collected from surveys, video and audio recordings, interviews, and field notes. In addition, a survey study with 31 parent participants and a focus groups discussion on design concepts for robots took place.

Deliverables:

1. Logo of the project (Figure 1)
2. Ethical approval application to TU/e and Medical ethical approval application to Radboud UMC
3. A short paper about the findings of this project phase was accepted at the HRI conference: Zhang, F. et al., "Understanding Design Preferences for Robots for Pain Management: A Co-Design Study", in *ACM/IEEE International Conference on Human-Robot Interaction*, 2022. The teaser for the conference presentation is shown in Figure 2.

Figure 1. Logo of the project.

Figure 2. Teaser for the paper presentation that resulted from the first phase of the project.

Phase 2 Technical developments

During this phase of the project the technical developments took place. These include the integration of the existing “Smart sock” wearable, a mobile application for pain signaling, and a robot in a way that the physiological signals are read by the wearable and signaled to the app and the robot to trigger comforting robot behaviors (Figure 3).

Figure 3. The wearable for measurement of pain related physiological signals and the emoticon expressing slight pain.

During the Phase 1 of the project, based on the co-design workshop [1] the Miro-e [2] robot was chosen as a pet-like social companion. The Miro-e is a cat-sized zoomorphic robot with 11 dof, stereo camerasin its eyes, and 4 directional microphones. It has soft silicone ears and muzzle and a hard plastic exterior with 28 capacitive touch sensors in its back and head. Six controllable led lights can be independently programmed to illuminate through its back casing. The ears, eyelids, and silicone tail can also be programmed to move. The Miro is programmable using either a blocks-based language (which is useful for rapid prototyping) or a ROS-based development toolkit for more advanced robot programming.

A. Software Developments

The ROS bridge was developed during the project to connect the wearable to Miro-e robot, or another robot that uses the Robot Operating System (ROS) [3] middleware. ROS isan open-source software development platform incorporating many existing tools and libraries that allows applications tobe run in a distributed manner, simplifying the integration of additional software modules (for sensor processing and other functionality) or hardware (such as novel interface devices or robots) into the existing system.

This system is adaptable and easily transportable to a hospital setting, including being able to run over Bluetooth and/or its wireless LAN or internet connection without requiring access to the hospital's network.

B. Robot Behavior Selection

To manage pain, the robot must be able to understand the internal state of the child and respond appropriately. However, the detection of pain and other important states (suchas alertness or desire to engage) through sensor data is likelyto be noisy. A controller for HRI should be able to handle the partial observability in this problem.
Partially observable Markov decision processes (POMDPs) are a formalism used for decision-theoretic planning that is able to represent partial observability and uncertain action outcomes [4]. The development of these models and the affective behaviors of the robot are ongoing.

Deliverables:

1. Integrating a system of Smart sock wearable the first version of AI algorithm for estimation of pain and the robot (Figure 3).
2. Prototypes of robot behaviors
3. The robot is being registered for use in the RUMC.

Phase 3 Tests in the clinics

Only preparatory steps for this phase have taken place during this project. We discussed all design and technology development steps with the Radboud Medical Center and Prof. Malagon in particular. During this collaboration, a medical-ethical approval waiver was obtained so the tests in the clinic can start. In addition, we are planning to submit a new funding proposal to be able to perform the clinical tests with the developed technology.

Deliverables:

1. Medical ethical approval waiver obtained by Radboud UMC

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The project builds on two ongoing collaborations between TU/e-VU on pain and stress detection through physiological measurements and collaboration between TU Eindhoven, Twente University, and Radboud Medical Center on developing child-robot interactions for pain management. The over 10 years TU/e-VU collaboration resulted in developing the

"Smart sock", i.e., a sock with embedded sensors that connects to a mobile application to visualize the pain and stress-related signals, which facilitated two Ph. D. projects. We would like to especially thank Prof. Paula Sterkenburg VU and the Ph. D. candidate Helen Korving (TU/e/VU) for facilitating knowledge transfer from our previous work to the current project.

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