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Measuring Physiological Data to Estimate Stress Through Robot-Orchestrated Interaction in Children’s Hospital

J. Giménez-Figueroa¹, H. Castaneda², Y. Benezeth², G. Álvarez-Benito³, L. Merino¹ and R. Gomez⁴

Abstract—Social robots are becoming important tools in hospitals. Currently, social robots are used to entertain children and distract them from their predicaments. In this paper, we leverage the characterful interface of a social robot in conjunction with a wearable sensor to gather physiological data and estimate stress. Initial studies show that children are accepting our system. The overall and long-term goal of our research is to develop a holistic social robot platform to study the interplay between interaction and human state understanding to improve well-being.

I. INTRODUCTION

The adoption of social robots in healthcare facilities like hospitals is growing. These robots are designed to interact with the patients and perform certain tasks. For example, Pepper [1] and Paro [2] are used to enhance human interaction, provide companionship, and emotional support. Social robots have the potential to improve the patients’ well-being. Children, in particular, are drawn to social robots due to their playful and approachable designs, which are helpful to reduce anxiety and make medical treatments less intimidating.

The use case scenarios of social robots in healthcare can be expanded when combined with devices measuring physiological signals from users to estimate internal states such as stress levels. One such device is the Empatica E4 [3], a wearable that measures physiological data like blood volume and skin conductivity, critical indicators of stress levels. In this paper, we describe the integration of the Empatica E4 sensor into the social robot Haru [4] to detect stress levels of children confined in the hospital through natural interaction as a proof of concept towards developing social robots for well-being in general. A social robot estimating internal states, such as stress levels, can enhance its interaction ability by regulating its actions according to the children’s internal states and proactively monitoring these states in real-time. The robot can also help children to become aware of their internal states by providing this information, which can be shared with carers or doctors.

II. METHOD

We have gathered a multidisciplinary team comprising medical doctors, psychologists, children advocacy groups and roboticists to design and implement the proposed system depicted in Fig. 1:

- 1) Conversation Content: in collaboration with scriptwriters ensuring fun, engaging, and educational content, tailored to different styles, topics, and genres for emotional

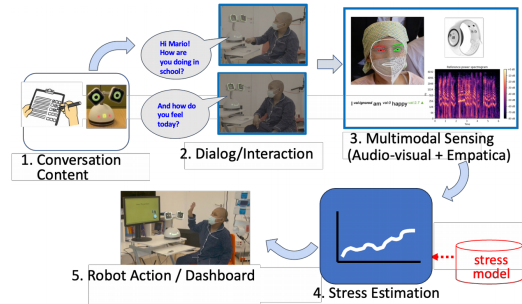


Fig. 1: Overall block diagram of the proposed system

support and enhancing the children hospital experience [5].

- 2) Dialog/Interaction: programming of content into the robotic system taking into consideration engagement, turn-taking, robot expressivity, etc. is key to the success of robot-orchestrated interactivity.
- 3) Multi-modal Sensing: perception of the children and the environment [6] helps the robot navigate its interaction, which includes audio-visual sensors and wearable sensors for measuring physiological signals.
- 4) Stress Estimation: stress is the body’s response to perceived threats and can negatively impact children’s well-being. In this paper, we measure stress using the physiological data provided by the wearable sensor using a stress model.
- 5) Robot Action and Dashboard: Stress information is used as one of the inputs to influence the robot’s response using both verbal and non-verbal cues, such as expressive routines. Furthermore, stress and other physiological readings are fed to the dashboard for doctors’ information.

The stress estimation is based on an AI model used to analyze physiological and behavioral signals provided by the E4 wristband. This stress prediction model relies on a Random Forest classifier that takes as input a set of 173 features calculated from 60 seconds of heart rate variability, electrodermal conductance, and accelerometer signals. These features describe the sympathetic and parasympathetic components of the autonomic nervous system. We extract frequency and time-domain features from the heart rate variability signals, descriptors of the phasic component and skin conductance level from the EDA signal, and statistical features from the accelerometer signals. The stress prediction model is trained using the WESAD database [7]

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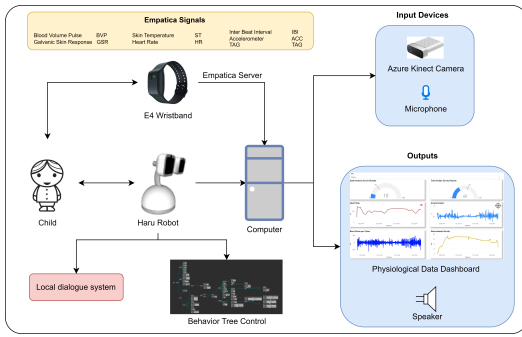


Fig. 2: System setup.

III. EXPERIMENTAL RESULTS

A. System Setup

The proposed system is shown in Fig. 2. Haru Robot, is the primary device interacting with and engaging the children. Haru Robot is connected to a PC, which is linked to three primary input devices: Kinect camera, microphone and the Empatica E4 sensor. These inputs enable us to capture both visual perception (non-verbal language: gestures, gaze, expressions) and auditory perception (verbal language), providing a comprehensive understanding of the child’s interactions. To monitor physiological signals, the child wears the E4 wristband. It transmits physiological signal to the computer, allowing real-time estimation of stress and visualization of other physiological data.

The Haru Robot is connected to the computer, enabling a continuous exchange of data during the Child-robot interaction. The Robot is controlled by the Behavior Tree Controller [8], which dictates its behavior, and includes a dialogue system, allowing the robot to engage in a meaningful conversation with the child. The computer transmits the Physiological Data Dashboard. The dashboard offers various visualizations of physiological data and detailed reports for each child, which are invaluable for doctors and nurses. This setup ensures that we can continuously monitor and analyze the child’s stress levels, providing real-time feedback and valuable data for healthcare professionals.

B. Pilot Study

We conducted two settings for our pilot studies. The first setting is the control, based on the conventional approach in which interviews were conducted by a human (i.e., psychotherapist). Following the ethics protocol, the sensors (i.e., mic and camera) were initially hidden while the Empatica sensor was worn like a normal wristwatch. After the session, the children are informed about the recording. The second setting is the robot-orchestrated interaction (proposed system) as shown in Fig. 2. Here, the robot controls the interaction with children, substituting the psychotherapist. In both settings, children wore the wearable to measure physiological data used to estimate stress. We had 7 cancer patients, and each session lasted 20-30 minutes. The multimodal perception of the system, including the reading of physiological data during our pilot study, can be displayed on a dashboard as shown in Fig. 3.

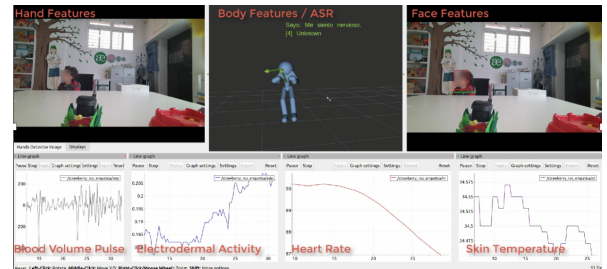


Fig. 3: Real-time data visualization during pilot study.

C. Results

We evaluated the stress classification performance with a rigorous *leave-one-subject-out* protocol, and achieved an accuracy of 86.4% and an F1-score of 84.8% when the stress prediction is formulated as a binary classification problem (i.e. stress vs. non-stress). Moreover satisfaction questionnaires were administered to the children, and the results were very positive. The children reported that they enjoyed interacting with the robot. Additionally, the hospital staff mentioned on several occasions that the physiological data collected were extremely useful to them, though they acknowledged the challenge of being able to constantly monitor these metrics.

IV. CONCLUSION AND FUTURE WORKS

We have built a prototype social robot system that monitors children’s stress through interaction. In a limited pilot study, we confirm the potential of the system to be accepted by children with acceptability rate matching those conducted by humans. In the future, we will be expanding the multimodal sensorial network to using other wearables (e.g. for measuring brainwaves, etc.) and measure other internal states such as focus, mood, anxiety, etc. with the purpose of improving children’s well-being in the hospital. Moreover, we will be conducting more studies with increased number of participants.

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