A haptic empathetic robot animal for children with autism

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A Haptic Empathetic Robot Animal for Children with Autism

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ABSTRACT
Children with autism and their families could greatly benefit from increased support resources. While robots are already being introduced into autism therapy and care, we propose that these robots could better understand the child’s needs and provide enriched interaction if they utilize touch. We present our plans, both completed and ongoing, for a touch-perceiving robot companion for children with autism. We established and validated touch-perception requirements for an ideal robot companion through interviews with 11 autism specialists. Currently, we are evaluating custom fabric-based tactile sensors that enable the robot to detect and identify various touch communication gestures. Finally, our robot companion will react to the child’s touches through an emotion response system that will be customizable by a therapist or caretaker.

CCS CONCEPTS
• Human-centered computing → Interaction devices; • Computer systems organization → Robotics.

KEYWORDS
socially assistive robotics, robot-assisted therapy, tactile sensors

1 MOTIVATION
Autism spectrum disorder (ASD) is a complex condition that impacts the individual on many levels, from neurological aspects to physical comorbidities. Children with autism often endure sensory overload from everyday stimuli [1, 6]. They may have difficulty with verbal communication, as well as with understanding and relaying emotions. These combined experiences can cause the child heightened stress during social interaction [10]. As the rate of autism diagnosis continues to rise in relation to the number of caregivers and educators, there is an urgent need for mechanisms to help children with autism learn to navigate exciting or unfamiliar situations.

While much work is being done to integrate robots into autism therapy and care [2, 5], tactile sensing is severely underutilized in comparison to other sensing modalities. Touch is a key tool for childhood development [7]. Furthermore, affective touch, or touch used to convey emotion, is crucial for bonding and social communication [6]. As children with ASD may struggle with visual or verbal emotion cues, touch is too crucial a communication channel to ignore for human-robot interaction (HRI). Inspired by the successes of deep-touch pressure therapy [9] and animal-assisted intervention (AAI) [13], we propose a touch-perceiving robot animal companion for children with autism. We refer to this robot companion, which can be seen in Fig 1, as the Haptic Empathetic Robot Animal, or HERA. We aim to investigate the hypothesis that a robot companion with good tactile sensing can help children with autism learn new skills and engage in social interaction.

2 COMPLETED WORK
Here, we present the work that has been completed toward making HERA a reality. We describe our process for creating a set of touch-perception guidelines and present a prototype robot system.
2.1 Establishing touch-perception guidelines with autism specialist interviews

Utilization of touch interaction during robot-assisted therapy is limited. Most robots in the field of socially assistive robotics (SAR) interact through predetermined routines, speech or visual cues, or remote control by a trained operator. These SAR systems may have either no touch sensing, binary on or off touch detection (e.g., NAO), or force level threshold detection at discrete points (e.g., KASPAR [14]). The range of touch-sensing abilities for existing robots suggests a lack of guidelines in regard to touch interaction. Therefore, we set out to define guidelines for the touch-sensing capabilities of a robot companion for children with autism [4].

We surveyed any mentions of touch in relevant HRI literature to construct an initial list of touch-perception requirements. To validate and refine our requirements, we conducted structured interviews with 11 autism specialists from a variety of occupations and with many years of experience (average: 13, median: 10, SD: 10). After systematically reviewing the interviews through thematic analysis [3], we finalized our initial list into seven qualitative requirements that a touch-perceiving robot companion for children with ASD should meet. These requirements provide guidelines on robustness and maintainability, sensing range, feel, gesture identification, spatial, temporal, and adaptation attributes.

By referencing established best practices in sensing, signal processing, and machine learning, we then transformed these qualitative requirements into quantitative specifications. These specifications are “approach-agnostic” and can be implemented by HRI researchers across many robot systems. The specialist interviews also enabled us to report several other important details, including locations on the robot’s body that children with autism are most likely to touch, touch gestures the children are most likely to perform, and recommended robot forms, behaviors, and roles.

2.2 Robot form factor

As we were inspired by the positive impact of animals and AAI on children with autism [12, 13], we sought to create an animal-themed robot. The majority of robot animals available on the market are toys with little to no sensing or reprogramming functionality. Rather than design a new robot, we elected to use a NAO by SoftBank Robotics for our prototype. NAO is an ideal robotic agent for our purposes due to its small stature, processing power, and ease of use. Furthermore, NAO is often used in robotic therapy studies with children with ASD [8, 16, 17], giving us confidence in its acceptability for our target audience.

Robots modeled after non-familiar animals, such as PARO the baby seal, are more accepted as credible social agents than familiar-animal robots, such as a cat robot [15]. This preference is due to users’ accumulated knowledge about familiar-animal behaviors and appearances through interactions with pets. We therefore decided to give HERA the outward appearance of a non-familiar animal by enclosing the NAO in a soft koala suit. This koala form factor also fit the appearance recommendations from the autism specialists.

3 ONGOING WORK

We set out to develop a robot companion that meets the qualitative requirements and quantitative specifications we defined. Our current work focuses on creating a tactile perception system and emotion response system for HERA.

3.1 Tactile perception system

As we did not find a readily available sensor that met our touch-sensing requirements, we decided to build our own. We especially sought to create sensors that could be easily integrated into existing robot systems for ease of setup by a therapist or caretaker. We have iteratively created and tested an external fabric-based piezoresistive tactile sensor system. When pressed with a contact area of 28.3 mm², our prototype demonstrated a robust sensing range from 0.5 N (light touch) to 15 N (strong contact). In a pilot study, an individual performed six types of communication gestures — squeezing, patting, scratching, poking, hand resting without movement, and no touch — on an individual sensor on a flat surface. Each type of touch gesture, which varied in contact duration and force, resulted in a unique resistance signature from the sensor, as seen in the sample trial shown in Fig 2.

We are presently evaluating our touch perception system’s abilities through a user study. We secured four sensors across the robot’s arm, as seen in Fig 1. We built each sensor to fit the curvature of its respective arm segment. 16 neurotypical participants conducted various touch gestures across HERA’s arm at both gentle and energetic force levels. We will use the sensor resistance data collected from our participants to evaluate the physical characteristics of our sensors and the robustness of our gesture classification algorithm.

3.2 Emotion response system

We aim to develop a realistic emotion system that will help children with autism understand the impact of their touch on others. Once the robot identifies that the user has touched it with a certain gesture and force, the robot should react accordingly. Additionally, HERA’s affective state will also be influenced by the full history of the various gestures it detects. We plan to draw inspiration from the TAME framework (Traits, Attitude, Moods, and Emotions) [11], showing that one’s emotional state is impacted by both internal and external factors with varying scales of time dependence.

We will develop a GUI that therapists can use to easily modify the TAME parameters, enabling the robot’s personality and responses to touch to be customized for each child. We then plan to test HERA together with therapists in a guided study with children with autism. We plan for HERA to remain seated on the ground or a table so that the interactions are calm, easy to monitor, and safe.

Figure 2: A sample gesture trial from our pilot study highlighting the various touches performed on the sensor.
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