Lend A Hand: Designing A Robot for Teaching Social Skills to Children with High-Functioning Autism

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***Abstract*—Children with high-functioning autism (HFA) face significant challenges in developing social skills. Over the years, some technology-assisted therapies for those children were developed and have proven effective. However, in real-world practices, these therapies have limitations, such as lacking of attractiveness to children. Therefore, we propose HAN, an interactive robot designed to teach social skills to children with HFA based on TIP (Teaching Interaction Procedure) therapy. We aim to design an attractive appearance and a series of attractive interfaces to provide a better therapy experience for children with HFA. We structured social interactions through teaching, interaction, feedback, and generalization; thus, HAN systematically taught a wide range of social skills through a comprehensive curriculum. We conducted a preliminary user test at a local autism intervention center and collected valuable user feedback.**

***Index Terms*—Interaction Design, Robot for Children, High-functioning Autism, Social Skills Development**

I. Introduction

Children with high-functioning autism (HFA) often possess average or above-average intellectual abilities [1], yet they face persistent challenges in developing social and emotional skills. These difficulties can manifest as poor eye contact, misunderstandings of non-verbal cues, difficulty in maintaining conversations, inappropriate emotional responses, and a lack of empathy [2]. Compared to children with general ASD, HFA children often face unique challenges. Since most HFA children attend regular classrooms, they face greater social pressures, increasing the risk of unemployment and poor social relationships in adulthood [3] [4].

Early interventions have proven crucial in addressing these issues [5], but access to quality therapy is limited, especially in developing regions. In China, for instance, there is an acute shortage of specialized therapists, with one therapist often serving over 2,500 children. In response to these challenges, we propose an interactive robot designed to teach social skills to children with HFA through the structured, evidence-based Teaching Interaction Procedure (TIP) therapy. Inspired by our slogan "lend a hand", we call our robot HAN (see Figure 1). HAN's goal is to provide a scalable, engaging, and effective solution to bridge the gap in social skills development for children with HFA.

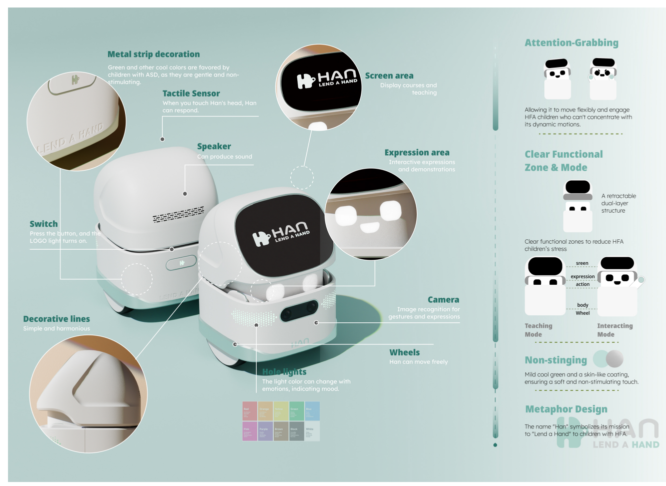

Fig. 1. The appearance and interaction design of HAN robot

II. Related Work

The Teaching Interaction Procedure (TIP) therapy, developed by Edward Phillips and colleagues, is a widely recognized intervention for teaching social skills. It uses structured interactive scenarios to help children understand, imitate, and apply appropriate social behaviors (see Figure 2). TIP therapy has demonstrated success in improving social interactions among children with autism. In one study, the correct social responses of children with HFA increased from 0.2 to over 0.8 after TIP intervention [6].

We chose TIP therapy for HAN because it is structured, evidence-based, and aligns well with the predictable nature of robot-assisted interventions. By focusing on teaching, interaction, feedback, and generalization, TIP provides a clear framework for teaching social skills. Its proven success in helping children with autism learn and imitate social behaviors makes it effective for both learning and real-world application.

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Research indicates that robots can be effective tools in autism interventions, particularly for improving social interaction, communication, and emotional expression in children with Autism Spectrum Disorder (ASD) [7] [8]. Since Weir's 1976 report on robotic interventions for autism, research has demonstrated that children with autism are more engaged with robots than with traditional therapy [9]. Studies have shown that robots can elicit more positive reactions than human interactions in some cases, especially for children with lower levels of disability [10]. Challenges remain in programming robots to meet individual needs and in using them as social mediators [11]. Despite these challenges, robots are considered promising tools for enhancing ASD research and treatment, providing a predictable and secure environment for children with autism [9]. NAO and JIBO, two widely used robots in therapeutic settings, have facilitated social learning by using facial expressions, gestures, and interactive tasks [12].

HAN builds upon these successes by integrating TIP therapy into its interactions, providing a structured framework for teaching social skills. This approach aims to ensure that children not only engage with the robot but also retain and generalize the social skills they learn in real-world situations.

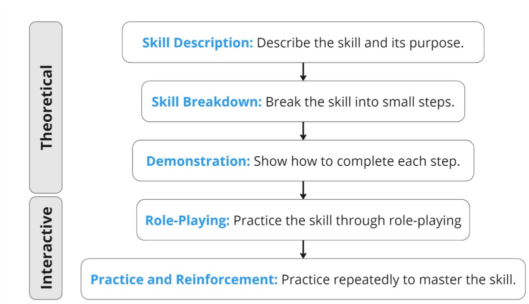

Fig. 2. The Teaching Interaction Procedure (TIP)

III. Design Development

A. User Research

Our study was conducted in China and complied with all relevant local regulations and ethical guidelines. According to these regulations, the study did not require additional approval from an ethics committee, as it did not involve animal or human clinical trials or any practices deemed unethical. Informed consent was obtained from all participants in accordance with the ethical principles of the Declaration of Helsinki. All identifying information was anonymized to ensure privacy and confidentiality.

To design an effective and engaging robot, we conducted a series of design studies with Qing (pseudonym), a 5-year-old girl diagnosed with HFA, and her mother. These studies aimed to understand the daily challenges Qing faces, her social skills development, and her specific needs.

1. Five-Week Observation and Laddering Interviews: Over five weeks, we conducted weekly interviews with Qing and her mother, focusing on Qing's daily experiences. Through structured "Why" questions, we uncovered her deepest needs, including her desire for order, difficulty building relationships, and struggles with self-control (see Figure 3).

2. Six-Hour Observation: We observed Qing during a typical day at home and school, identifying pain points such as her difficulty focusing on tasks, insistence on routine, and challenges in recognizing social cues from her peers (see Figure 4).

3. Contextual Inquiry: A three-hour observation during one of Qing's home-based social skills intervention sessions highlighted additional challenges with existing therapies, including her aversion to real-person teaching and difficulty focusing on theoretical learning.

The insights from these studies informed the design of HAN, ensuring it would meet the specific needs of children with HFA such as Qing.

B. Design Insights

Attention to Detail: Children with HFA often struggle with distractions. HAN's design incorporates simple, clean interfaces that minimize distractions.

Routine and Structure: The robot's interactions are predictable and follow a clear structure, making it easier for children to follow and learn.

Engagement: HAN's appearance and interactions are designed to be engaging and appealing, making the learning process enjoyable rather than overwhelming.

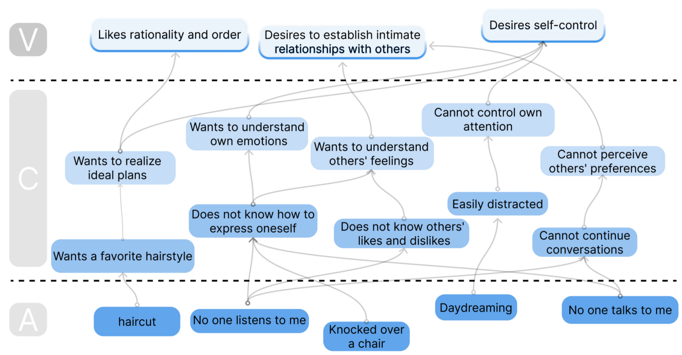

Fig. 3. Laddering interview results

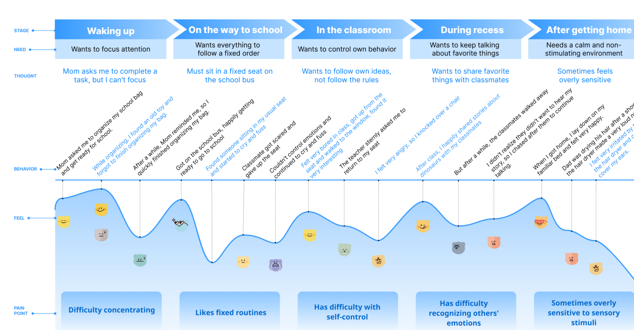

Fig. 4. User Journey Map

C. Implementation

We developed the HAN prototype through an iterative process that integrates hardware assembly and software development (see Figure 5).

Fig. 5. Three interaction modes of HAN robot

We developed the HAN prototype through an iterative process that seamlessly integrates hardware assembly and software development, drawing inspiration and technical insights from the open-source project ElectronBot.

Here we describe the key implementation details.

D. Hardware Development

The prototype uses an ESP32-S3 microcontroller for processing and connectivity. The physical structure was designed in Rhino and 3D-printed using white PLA material, featuring a dual-screen setup and modular construction for maintenance access.

We implemented dual screens with distinct functions. For upper screen, we used 3.15-inch capacitive touchscreen (320*240) for interactive teaching content. For lower screen, we used 1.68-inch OLED display (240*240) for emotional expressions. For input and output, we used six servos (GH-S37A) for gestures, a microphone (MAX98144) for voice input, 3W stereo speakers for audio output, and a camera (GC0307) for recognition tasks. For movement, our prototype utilized a rotating base rather than a wheeled design. Custom PCBs were developed to manage power distribution and control signals between components.

E. Software Development

We used Figma to design the user interfaces. The color scheme primarily uses deep green, black, and gray tones - colors that are proven to be non-stimulating and comfortable for children with sensory sensitivities common in HFA.

The core functionalities we designed and developed are: (a) speech processing, (b) motion control, (c) audio system, and (d) expression recognition. For speech processing, we combined ChatGPT with Whisper API [13], to make HAN understand synonymous instructions (e.g., “hands up” and “raise your hands”). For motion control, we used servo control algorithms for generating appropriate gestures. For the audio system, we used using ChatGPT API for generating context-aware and conversational responses, paired with Google Cloud Text-to-Speech [14]. For expression recognition, we utilized the DeepFace framework combined with OpenCV.

IV. Interaction Design and Context of Use

HAN features a user-friendly interface and expressive movements designed to enhance interaction with children (see Figure 6). The robot’s design includes:

Screen-based Guidance: HAN incorporates two interactive displays connected by a scalable structure, offering a dual-screen interaction method. A display on HAN’s body shows visual aids and cues, reinforcing the social skills being taught.

Gestures and Expressions: HAN uses non-verbal cues, such as gestures and facial expressions, to model appropriate social behavior.

Physical Interaction: The child can interact with the robot through touch, enabling hands-on learning experiences that reinforce the lessons.

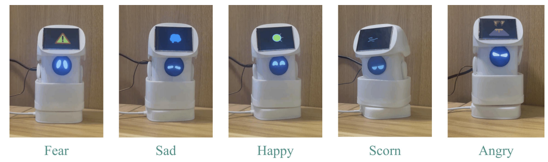

Fig. 6. Dual-screen interactive design to express feelings

The interaction design of HAN revolves around the principles of TIP therapy, structured into four key stages (see Figure 7):

Teaching: The robot provides an explanation of the social skill being taught, using simple language and visual aids.

Interaction: The child engages in a role-playing scenario with the robot, practicing the social skill in a controlled environment.

Feedback: The robot offers immediate feedback on the child’s performance, reinforcing correct behavior and gently correcting mistakes.

Generalization: The robot encourages the child to apply the skill in real-world situations, using prompts to help the child recall and use the skill outside the therapy session.

These interactions are designed to be playful and intuitive, reducing the cognitive load on the child while promoting engagement.

Fig. 7. A teaching scenario based on TIP therapy

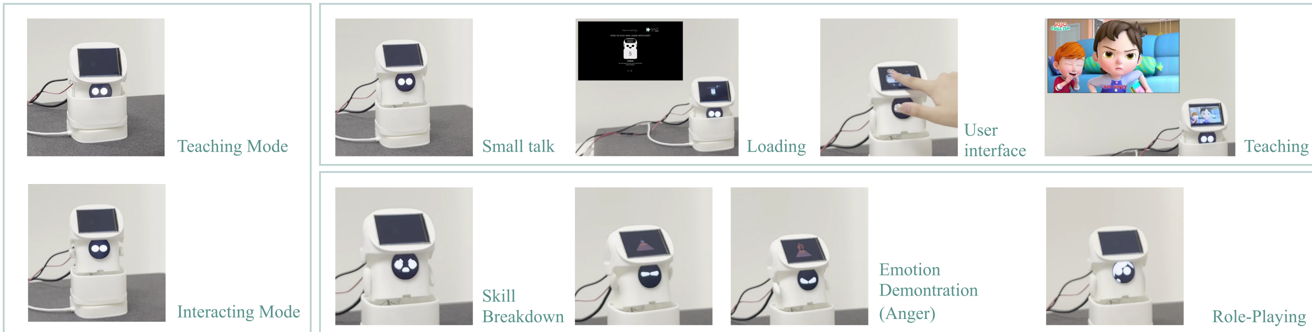

Fig. 8. The working prototype of HAN with different scenarios

V. User Interaction

We conducted a preliminary user test at a local autism intervention center where we have established a collaborative relationship. The participants included three children with HFA (aged 5-8) from diverse backgrounds, one intervention therapist, and two parents. During the 15-minute sessions, participants interacted with HAN through several social skill learning scenarios: greeting others appropriately, recognizing and responding to basic emotions, and taking turns in conversation etc (see Figure 8). In one scenario, HAN taught proper greeting behaviors by demonstrating the sequence of making eye contact, saying hello, and waving - a daily challenge reported by parents.

The dual-screen design proved particularly engaging for the children, with one 7-year-old commenting "I can see what HAN is feeling while learning!" The therapist noted that the separation of teaching content and emotional expressions helped children better understand the connection between social scenarios and appropriate emotional responses. Parents appreciated the structured, predictable interaction flow, with one mother observing that her child remained unusually focused throughout the session. The children showed particular interest in HAN's facial expressions, often mimicking them and trying to predict the robot's next response. However, both the therapist and parents raised concerns about the durability of certain components, suggesting additional protection for the screens and moving parts. They also recommended incorporating more physical safeguards, such as rounded corners and secure mounting of the screens. These initial interactions provided valuable insights for improving both the physical design and interaction flow, while validating our core approach of using dual-screen interaction for social skills education.

VI. Conclusion and Future Work

Through careful design studies and the application of TIP therapy principles, we developed HAN, an interactive robot designed to help children with high-functioning autism learn social skills in a structured and engaging manner. By integrating user feedback and insights from real-world observations, we created a robot that addresses the specific needs of children with HFA, providing an accessible and scalable solution to the social challenges they face.

In future work, we plan to expand the scope of our user studies, incorporating feedback from a larger sample of children and caregivers to further refine HAN's design and interaction framework. Additionally, we aim to explore long-term impacts by studying the generalization of skills learned with HAN in everyday social situations. We also envision incorporating artificial intelligence to personalize the learning experience for each child, adapting the therapy to their unique progress and needs.

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