

An Empathetic Social Robot with Modular Anxiety Interventions for Autistic Adolescents

Baijun Xie¹ and Chung Hyuk Park²

Abstract—Autistic individuals, or individuals diagnosed with autism spectrum disorder (ASD), often experience challenges in social relations and may experience increased stress or anxiety. Recent studies highlight the potential of socially assistive robots (SARs) as tools for robot-assisted interventions. However, current human-robot interaction (HRI) designs lack consideration for the diverse anxiety issues in individuals with ASD and the need for personalized, empathetic assistance. The question that persists is whether the most recent individualized and modular intervention program for autism can also be effectively implemented through the use of SARs. This study presents a novel HRI framework that incorporates psychological factors into a modular intervention aimed at reducing user's anxiety levels. The developed system integrates techniques such as human pose estimation and motion imitation while also leveraging conversational agents. During the user study, users engaged in interactions with a humanoid robot equipped with multiple intervention modules, and their anxiety and perceptions of the robot's empathy were assessed through questionnaires in a within-participants study design. Results show the implemented system effectively mitigated users' anxiety by assessing the differences between pre-session and post-session scores. Additionally, our findings suggest that the observed change in empathetic scores may be a contributing factor to the reduction in anxiety levels. The study offers significant insights into the use of SARs for mental health support in autistic adolescents.

I. INTRODUCTION

Autistic individuals, or individuals diagnosed with autism spectrum disorder (ASD), often experience challenges in social interaction and engagement. Moreover, the prevalence of mental health disorders is considerably higher among autistic individuals when compared to the general people [1]. Particularly, it has been estimated that 39.6% of young individuals with autism experience symptoms of anxiety [2]. Anxiety and inadequate stress management are prevalent issues observed in the clinical populations of adolescents diagnosed with ASD [3]. One of the challenges encountered by both their parents and healthcare providers is the imbalance between the demand for anxiety treatment and the availability of specialized resources.

Socially assistive robots (SARs) [4], [5] have become significantly popular as effective tools for intervention in ASD based on many human-robot interaction (HRI) studies

conducted over decades [6], [7]. These robots are currently widely utilized in special education [8], [9], autistic care facilities [10], [11], and clinical settings [12], [13]. The field has recently found that interventions utilizing SAR for ASD have the potential to produce beneficial impacts on mental health outcomes, including the alleviation of distress and the enhancement of positive effects [14], [15]. Social robots have the potential to serve as an advantageous component within robot-assisted interventions for individuals with social anxiety. It is important to note that these robots should not be viewed as a substitute for clinicians but rather as a complementary tool for supporting their work [16]. Further studies are needed to identify the most effective and readily implemented robotic interventions in mental health care.

Traditionally, interventions used for adolescents diagnosed with ASD comprise Applied Behavior Analysis [17], speech and language therapies [18], and educational methodologies [19]. Moreover, cognitive behavioral therapy (CBT) has been identified as the most common approach for addressing concurrent anxiety-related symptoms in children and adolescents diagnosed with ASD [20]. Nevertheless, it is important to note that the existing CBT program developed for the general population may not provide desirable outcomes when used for those diagnosed with ASD [21]. This is mostly because autistic individuals frequently have a comorbidity, wherein they simultaneously exhibit multiple distinct disorders [22].

Recent studies have investigated the utilization of modularized programs to mitigate emotion regulation impairments [23] and decrease anxiety in individuals with ASD [21]. The study conducted by Parr et al. [21] examined the effectiveness of personalized anxiety treatment in meeting the specific requirements of autistic adolescents by implementing an individualized psychological treatment protocol. The protocol was established through a customized, modular, and personalized treatment framework that incorporated a range of therapeutic methodologies, such as mindfulness, strategies for managing uncertainty, and addressing social anxiety. The findings of these studies provide evidence in support of the viability of the program for participants with emotional and anxiety disorders.

The aforementioned methodologies can also be employed in the utilization of SAR in robot-assisted interventions, as outlined in [16]. These interventions encompass a variety of HRI scenarios, including participation in social games, simulation of social situations, and involvement in mindfulness practices. However, there are still deficiencies in the implementation of individualized robot-assisted interventions

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¹Dr. Baijun Xie is with the Department of Biomedical Engineering, School of Engineering and Applied Science, The George Washington University, Washington, DC 20052, USA bdxie@gwu.edu

²Dr. Chung Hyuk Park is with the Department of Biomedical Engineering & Department of Computer Science, School of Engineering and Applied Science, The George Washington University, Washington, DC 20052, USA chpark@gwu.edu

for alleviating the anxiety of individuals with ASD, as only a limited number of current studies have investigated the factors that influence the effectiveness of HRI in this context. A previous study demonstrates that individuals with social anxiety disorder who possess a higher level of cognitive and emotional empathy are able to mitigate the negative effects of acute stress on their social behavior [24]. It was also found that patients with elevated baseline anxiety were less anxious after receiving verbal empathy and physical touch from a bronchoscopist prior to a bronchoscopy [25]. These investigations have indicated that *empathy* has the potential to mitigate anxiety and stress within healthcare settings. Empathy is an essential component of human social communication, representing an individual's inherent ability to effectively understand and react to the emotions experienced by others [26].

Empathy also plays a crucial role in studying human-robot relationships, making it a significant component within the domain of HRI [27]. One previous study assessed brain activity while participants observed emotional movements executed by humanoid robots [28]. The findings indicated that robots capable of simulating human-like behaviors elicited a greater degree of empathy from users. Additionally, there has been an investigation into whether the utilization of imitation interaction can be an effective strategy for fostering motivation and engagement among individuals diagnosed with ASD [29]. Furthermore, Javed et al. [30] explored the design and evaluation of a SAR with emotional capabilities to address empathy and emotion regulation impairments in individuals with ASD, extending beyond its traditional roles in learning and social skills training. Building upon the findings of previous studies, this study attempts to develop a SAR framework that seamlessly delivers empathy responses and engaging behaviors to enhance the user's experience during the HRI. It focuses on designing an HRI framework that meets the demands of individuals with ASD who experience symptoms of anxiety, incorporating a modularized, customized, and empathetic intervention program. Moreover, this study also investigates the impact of empathy on anxiety reduction effectiveness. The main contributions of this study are listed as follows:

- A modular, personalized, and empathetic HRI framework for reducing anxiety in ASD is developed, where the HRI scenarios are tailored to each participant's circumstances and preferences. The robot can deliver empathetic responses and exhibit engaging behaviors during interactions.
- The ability of the proposed system to mitigate participants' anxiety levels is investigated through a user study.
- To the authors' knowledge, this study is a pilot exploration that examines the correlation between anxiety reduction and the level of empathy experienced by individuals with ASD, exploring the impact of empathetic factors in SAR on mitigating anxiety symptoms.

II. RELATED WORK

SARs have garnered significant attention in recent decades, with extensive discussions surrounding their potential uses in mental care interventions [13]. SAR is regarded as a means to leverage the clinical advantages associated with animal-assisted therapy while bypassing the difficulties associated with using actual animals. A baby harp seal robot, PARO, was created as a pet therapy for the mental health of the elderly [31]. It was also observed that children who engaged with PARO showed a decrease in stress levels and elicited positive moods [32].

Another application of SARs in mental health serves as a playmate that facilitates the practice and development of socially relevant skills, particularly in children diagnosed with ASD. The majority of SARs employed in interventions for autistic children employ imitation as a primary strategy, which involves the use of humanoid robots with basic imitation games that children may actively participate in [33], [34], [35]. Recent studies further explored utilizing customized social games that leverage the humanoid robot's gestural imitation abilities to improve engagement [36], [37]. The implementation of SAR also has the potential to enhance the social interaction abilities of autistic children, which can be achieved through eliciting social behavior and providing positive feedback [38].

SARs can also act as tutors, offering direct guidance and supervision to participants involved in relevant interventions. Kaspar [39] is a humanoid robot designed to assist autistic children, which has also been explored in current education and therapy interventions for children with ASD [40]. Furthermore, in an HRI scenario, the children are the teachers providing positive or negative reinforcement to Kaspar for it to learn a simple association game [41].

Furthermore, SARs have the potential to aid in the alleviation of anxiety symptoms among individuals diagnosed with ASD. A preliminary investigation was conducted to assess the effectiveness of an intervention program aimed at reducing social anxiety and enhancing social skills among adolescents diagnosed with ASD [42]. The results showed that the ASD group had a significant decrease in levels of social anxiety. A recent study has also indicated that interventions utilizing a robot have the potential to enhance motivation among individuals with anxiety disorder who are also diagnosed with ASD and are unable to verbally communicate in public settings [43].

Unlike previous literature, this study explores various roles a robot can fulfill in HRI scenarios, including companion, social mediator, instructor, and playmate. Each role is accompanied by a module with specific psychological goals.

III. METHODOLOGY

A. Robotic System

The multi-sensory, modular robotic platform used in this study is shown in Figure 1. The Pepper robot, from Softbank Robotics [44], is designed for social interactions using verbal communication, gestures, and a touchscreen. It features

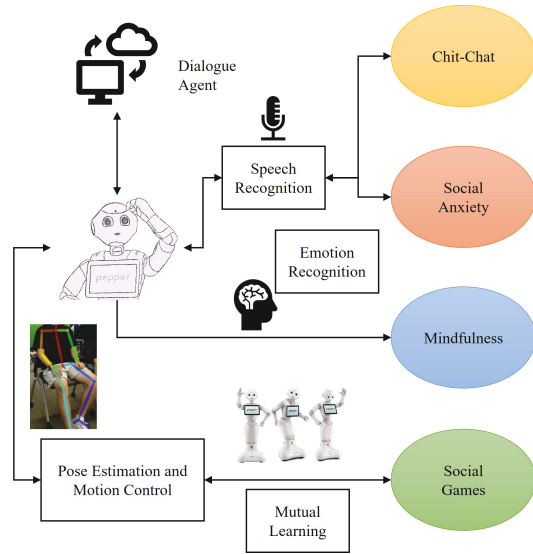


Fig. 1. The overview of the empathetic social robot with modular anxiety interventions.

NAOqi APIs in Python for joint control, face recognition, and text-to-speech modules.

Kinect sensor with the OpenPose [45] software is utilized for tracking the 3D pose keypoints of the users. The Pepper robot's upper body movements are mapped from these skeleton keypoints, and joint angles are obtained using a motion retargeting algorithm [46]. These techniques facilitate the development of an interactive gaming scenario in a mutual learning scheme.

During the interaction, a microphone and two cameras are used: one captures user activities, and the other records the Pepper robot's actions. The microphone captures high-quality sound for speech recognition. All inputs—video, audio, and text—are stored for future emotion recognition analysis to enhance personalization.

B. Framework Design

The proposed intervention program consists of four modules: Chit-Chat, Social Anxiety, Mindfulness, and Social Games. These modules correspond to diverse psychological aspects of building rapport, emotion regulation, mental health, and trust, respectively.

The first two modules, Chit-Chat and Social Anxiety, are developed based on an artificially intelligent dialogue agent. It is challenging for conventional HRI with rule-based dialogue policies as these rules are susceptible to being broken and need significant time and effort to develop and sustain. The recent progress in the development of large language models (LLMs), such as ChatGPT [47], presents a significant and revolutionary potential for the field of HRI. LLMs exhibit an exceptional capacity to comprehend contextual information and engage in natural interactions with users, which closely resembles human-like capabilities. In this study, OpenAI APIs were employed, specifically utilizing the InstructGPT model [48], to analyze and comprehend

the dialogue inputs provided by the user and subsequently generate appropriate responses.

Additionally, our research endeavors to examine the long-term effects of the proposed intervention program. Hence, there is a desire for the personalization of the system. Given the utilization of a within-participants design to investigate the impact of the intervention, it is plausible that the obtained results may be susceptible to order effects. The order effects observed in the within-participants design in HRI have been investigated and described in a previous study by Hoffman et al. [49]. These order effects encompass several factors such as familiarity, novelty, habituation, learning, and fatigue. Counterbalancing is widely recognized as the most common method for mitigating order effects [49]. However, counterbalancing isn't feasible in this study due to the need for prior user data to personalize interactions. Instead, we explore other ways to mitigate order effects. The following sections discuss the implementation and personalization of each module, considering potential order effects.

Chit-Chat. The Chit-Chat module aims to help the robot build rapport with the users. The Pepper robot first introduces itself and asks general questions, such as "How is your semester going?". After each question, Pepper provides a response generated by the ChatGPT dialogue agent, which is prompted to generate friendly replies based on participants' inputs. In the second session of the user study, the Pepper robot will initially engage in user identification and express greetings to them. Furthermore, in contrast to the first session, the second session features different questions to encourage varied responses and mitigate the novelty effect.

Social Anxiety. In the Social Anxiety module, Pepper inquires about the users' personalized experiences and feelings about anxious situations in their daily lives. This module intends to improve the user's ability to understand and express their emotions and feelings in various social contexts, analyze the impact of these situations, and find appropriate ways to regulate their emotions. After each question, the dialogue agent is prompted to deliver empathetic responses and offer advice. Potential order effects in this module include fatigue and habituation, which may arise due to the structured questions related to recent anxious events that participants have experienced. Consequently, we arranged an adequate break of no less than one week between the sessions to alleviate the effects.

Mindfulness. The Mindfulness module contains several mindfulness practices tailored for adolescents, as summarized in previous literature [50]. This module offers users the possibility to gain the skills to mitigate emotional distress in everyday situations. During their interaction with this module, participants receive guidance from Pepper on mindfulness practices. Three specific practices are used: the Body Scan, Breathe and Smile, and SOBER Breathing Space. The module is personalized by offering a different mindfulness practice in each session.

Social Games. The Social Games module is developed based on an interactive social gaming scenario, specifically the "charades game", which was proposed in our previous

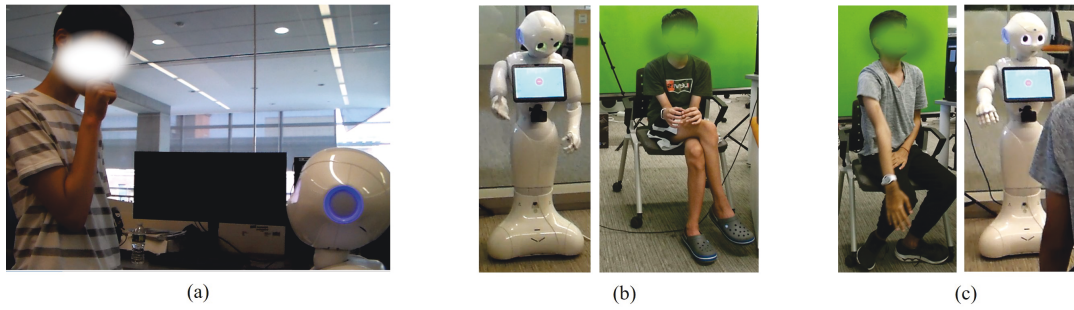


Fig. 2. The illustrated pictures capture autistic participants interacting with the Pepper robot in different modules: (a) Chit-Chat and Social Anxiety modules: the participant participated in a conversation with Pepper, during which he shared his personal experiences related to anxiety; (b) Mindfulness module: the participant followed Pepper's instructions for the different practices; (c) Social Games module: the participant engaged in a Charades game where he acted a word for Pepper to guess, while Pepper imitated his gestures and learned new moves.

study [37]. The Pepper robot primarily engages in four different genres of Charades words, including movies, sports, social behaviors, and emotional gestures. A mutual learning scheme is employed to design the HRI scenario. During the HRI, Pepper initiates the request for users to participate in games. If the users agree to participate, Pepper proceeds to execute a series of pre-defined charade words, which are derived from the initial database of collected behaviors, for the users to attempt to guess. Then, Pepper encourages users to act out their preferred charade words while it tries to guess in turn. Moreover, Pepper has the capability of imitating users' gestures during their actions, promoting a heightened sense of empathy between the robot and its users. This mutual learning framework allows Pepper to learn new gestures from users, while users benefit from the creative aspect. The objective of this module is to facilitate the development of self-assurance among individuals with ASD, thereby fostering their willingness to engage in social interactions in daily life. Additionally, this module contributes to the increase in social intelligence of the robot, enabling longer-term interactions and increasing the interest levels of users over time.

C. Participants

Participants were recruited through flyers, online postings, and email invitations, targeting adolescents aged 13 to 19. The study involved 22 adolescents: 7 with ASD and 15 typically developing (TD). The average age was 16.10 years ($SD = 1.77$), with seven females and fifteen males. The ASD group had an average age of 15.28 years ($SD = 2.05$), all males. The TD group had an average age of 16.5 years ($SD = 1.45$), with seven females and eight males. Participants included 4 undergraduates, 14 high school students, and 4 middle school students.

D. Measures

1) *Quantitative Data:* Three different quantitative questionnaires were considered in this study: the Anxiety Scale for Autism-Adults (ASA-A) [51], the Hospital Anxiety and Depression Scale (HADS) [52], and an adapted version [53] of Robot's Perceived Empathy (RoPE) scale [54].

The ASA-A is a 20-item self-reported scale designed to assess anxiety in adolescents with autism. It includes a general anxiety factor and three specific factors: social anxiety, anxious arousal, and uncertainty. The scale provides an overall anxiety score and specific component scores by summing items in each group. Each item is rated from 0 ("never") to 3 ("always") on a four-point Likert scale. A score of 28 or higher may indicate significant anxiety levels.

The HADS is a widely used 14-item self-reported questionnaire to assess anxiety (7 items) and depression (7 items) in various communities and psychiatric populations. Scores from 0 to 7 are considered normal, 8 to 10 are borderline abnormal, and 11 to 21 are abnormal.

The modified RoPE questionnaire is a 25-item self-reported survey with three subscales: empathic understanding, empathic response, and empathic relationship. It adds five questions to the original RoPE to explore interactive capabilities in HRI. Responses are rated on a five-point Likert scale from "Strongly Disagree" to "Strongly Agree."

2) *Qualitative Data:* Participants were asked about their willingness to return for another session after the first one. They were also asked for their perspectives on the Pepper robot, both positive and negative, and for suggestions for potential system improvements.

E. Study Design and Analysis

A within-participants study design was employed to assess the participants' scores before and after the intervention, allowing for a comparison of the changes between pretest and posttest scores. Baseline evaluations refer to the questionnaires given before the first session. The second session is scheduled at least one week after the first session. Each session includes both pre-session and post-session questionnaires. The study measured participants' anxiety levels (the ASA and HADS scores) and their attitudes toward the robot's empathy (RoPE score). The dependent variables were anxiety scores, and the independent variable was the robot's empathy.

The Shapiro-Wilk test was conducted on the baseline dependent variables, revealing that they were normally distributed. Consequently, parametric tests were employed for subsequent investigations. To evaluate the outcome, the

paired-sample t-test was utilized to analyze the differences between the pretest-posttest results and the disparities between the initial and subsequent sessions. Additionally, an investigation was conducted to assess the relationship between the dependent and independent variables, and statistical significance was established using Pearson's correlation coefficient. The significant level for those analyses was all set at $p < 0.5$.

F. Experiment Protocol

This study was approved by the University's Institutional Review Board (GW IRB 111540). Participants signed consent and video/audio release forms, with guardians signing for those under 18. They then completed questionnaires, including ASA-A, HADS, and RoPE. The Pepper robot introduced itself and conducted each module in sequence. Participants could skip modules they didn't want to complete. After all sessions, participants filled out post-session questionnaires, similar to the pre-session ones but with "After interacting with Pepper..." added.

IV. RESULTS

To validate the effectiveness of the designed framework, the following hypotheses were tested:

H₁: After the proposed intervention program, participants will report elevated empathy scores toward the robot and decreased anxiety scales for both ASD and TD groups.

H₂: The rise in empathy scores will be correlated with the decrease in anxiety scales for both ASD and TD groups.

H₃: All participants who attended the second session will have final measures (post-session questionnaires) with:

H_{3A}: higher scores than baselines for RoPE, and

H_{3B}: smaller scores for ASA and HADS.

A. Pre-Session vs. Post-Session Measures

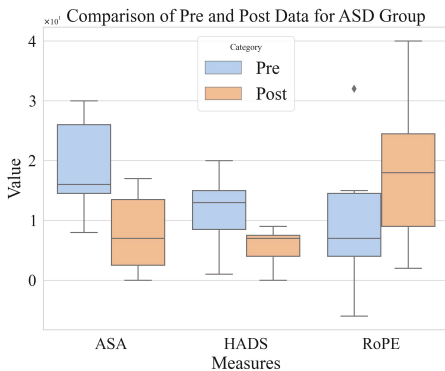


Fig. 3. The outcomes of the pre-session and post-session measurements for ASD group.

1) *Anxiety*: As shown in Figure 3, the average ASA and HADS scores of pre-session (ASA: $M=19.64$, $SD=7.36$, HADS: $M=12.18$, $SD=5.44$) for the ASD group were higher than the scores of post-session (ASA: $M=7.91$, $SD=6.13$,

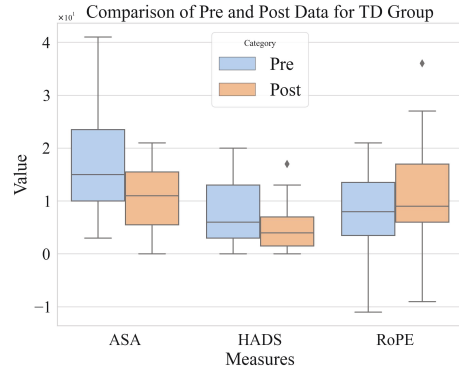


Fig. 4. The outcomes of the pre-session and post-session measurements for TD group.

HADS: $M=5.73$, $SD=2.63$), and both are statistically significant ($p < 0.001$) and showing large effect size (Cohen's D : 2.62 for ASA, 1.71 for HADS).

Figure 4 demonstrates the average ASA and HADS scores of pre-session (ASA: $M=17.48$, $SD=10.22$, HADS: $M=8.35$, $SD=6.47$) for the TD group, which were also significantly higher ($p < 0.001$) than the scores post-session (ASA: $M=10.65$, $SD=6.48$, HADS: $M=5.57$, $SD=5.22$) with a large effect size for ASA (Cohen's D : 1.04) and medium effect size for HADS (Cohen's D : 0.73).

2) *Empathy*: The RoPE scale for the ASD group from the pre-session ($M=9.18$, $SD=9.66$) was significantly lower ($p < 0.001$) than that of the post-session ($M=17.82$, $SD=10.53$), with a large effect size (Cohen's D : 2.23). In terms of the TD group, the RoPE scale from the pre-session ($M=7.78$, $SD=7.91$) was also lower than the post-session ($M=11.48$, $SD=9.89$), which is significant ($p < 0.05$) with a medium effect size (Cohen's D : 0.55).

Thus, based on the outcomes from both anxiety and empathy questionnaires, **H₁** is supported.

3) *User's Experience and Comments*: Before each module, Pepper asks the user if they wish to participate, allowing them to opt out. In the user study, one autistic participant was reluctant to engage with the Social Anxiety module, and one TD individual skipped the Social Games module in the second session. Nevertheless, the autistic participant was enthusiastic to engage in the Social Anxiety module on the second visit. All participants expressed a desire to return for the next visit. Feedback on the Pepper robot revealed concerns from two TD participants about its rapid speech, prompting a speed reduction in later studies. Three TD participants noted Pepper's delayed reactions, which should be due to the processing time for speech recognition and the cloud-based dialogue agent.

B. Correlation Analyses

The difference in the measures between the pre-session and post-session scores are calculated and investigated by correlation analysis as represented in Figure 5. For the TD group, significant correlations have been found between the RoPE difference and the ASA difference ($r = -0.365$, $p =$

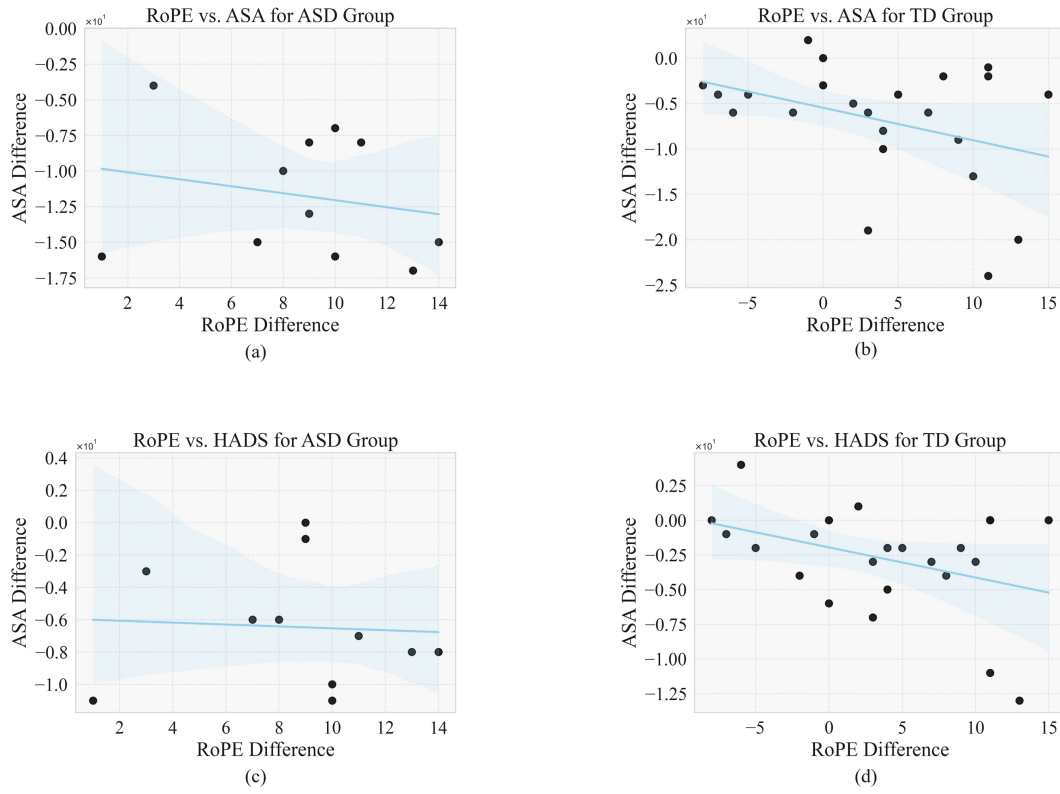


Fig. 5. The correlations in the differences of pre-session and post-session measurements for the ASD and TD groups.

0.043) and the RoPE difference and HADS difference ($r = -0.383, p = 0.036$). However, for the ASD group, the correlations between the RoPE difference and the ASA difference ($r = -0.213, p = 0.265$) and the RoPE difference and the HADS difference ($r = -0.06, p = 0.430$) are not statistically significant. Therefore, H_2 is partially supported in overall.

C. First-Session vs. Second Session

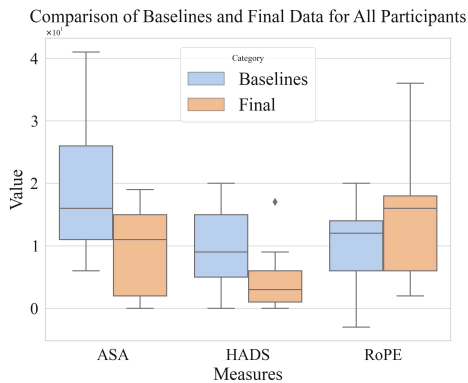


Fig. 6. The outcomes of comparing the participants' first and second session measurements.

13 participants have attended both sessions, and the final average RoPE score ($M=13.85, SD=9.24$) is significantly ($p < 0.05$) higher than the average baseline RoPE ($M=9.92,$

$SD=6.13$) with a medium effect size (Cohen's D : 0.55). Thus, H_{3A} is supported.

Regarding the anxiety scales, the final ASA score ($M=8.92, SD=6.83$) is significantly ($p < 0.001$) lower than the baselines ($M=19.54, SD=9.66$) with a large effect size (Cohen's D : 1.4), and the final HADS score ($M=4.54, SD=4.62$) is also significantly ($p < 0.001$) lower than the results of the baseline ($M=10.0, SD=6.59$) with a large effect size (Cohen's D : 1.22). Consequently, both H_{3A} and H_{3B} are supported.

V. DISCUSSION

A. Outcome Measures from the User Study

Two anxiety scores were utilized to ensure that all groups accurately represented complete outcomes. It was anticipated that the proposed robot-assisted intervention program would effectively mitigate anxiety levels in both the groups diagnosed with ASD and TD individuals. The results of our study indicate a statistically significant drop in scores on both the ASA and HADS scales when comparing pre-session and post-session assessments. In addition, it was hypothesized that the users' attitude toward the robot's empathy would be positively influenced following the intervention. The findings additionally validated the stated hypothesis. Therefore, the findings of this investigation provide support for H_1 . Additionally, a comparison was conducted between the baselines and final scores among participants who joined the second session, providing support for H_3 . Nevertheless, a portion of

the participants were unable to attend the second session as a consequence of schedule constraints.

Those promising findings demonstrate the efficacy of including modularized intervention programs in the design of interactive scenarios for human-robot interaction (HRI), which is also supported by existing literature in the domains of mental health care [21], [23] and robotics [16].

B. Correlation Between Anxiety and Empathy Scales

It was hypothesized that an increase in the RoPE scale would correspond with a decrease in anxiety following the intervention. As elucidated in the results, this was significantly observed only in the TD group, partially supporting **H₂**. This was unsurprising due to the limited sample size for the ASD group. While the correlation between RoPE and ASA wasn't statistically significant in the ASD group, RoPE showed a stronger correlation with ASA than with HADS, suggesting ASA may be a more suitable metric for assessing anxiety in individuals with ASD.

C. Limitations

This study is subject to several limitations. The sample size for the ASD group is limited, and there is an imbalance in the gender ratio within this group. The task of achieving a balanced gender ratio for the user study, particularly within the ASD group, was found to be exceedingly challenging. In addition to the limited sample size, the study is conducted without the inclusion of a control group, a decision that can be attributed, at least in part, to the above-mentioned sample size limitations. Another significant challenge of introducing a control group is that it limits the study's ability to properly control how well the robot can demonstrate empathy and ensure the delivery of interventions in the context of HRI. Since the study focused on HRI, it would be unfair to have participants, especially those with ASD, attend without seeing a robot. Therefore, a within-participants study design was deemed appropriate for the current setting.

VI. CONCLUSIONS

The present study contributed by developing a novel SAR framework that specifically focuses on empathy and mental health. The proposed framework integrates a modularized program that encompasses several psychological components to facilitate robot-assisted interventions. The HRI scenarios included in this study were specifically crafted to foster the development of empathy among the participants. Multiple outcomes were revealed, one of which indicated that the participants exhibited a greater inclination towards the robot's capacity for empathy while also experiencing a reduction in anxiety levels after the interventions with the robot. It is expected that the change in the empathetic scores would correlate with the change in the anxiety levels; however, this was only found in the TD group. Nonetheless, the proposed robotic framework and the intervention program we devised demonstrated effectiveness in the user study.

In future endeavors, we anticipate conducting a more comprehensive examination of the salient determinants that

facilitate the development of empathy and the alleviation of anxiety among users. The existing framework encompasses several modules; yet, certain modules may be preferred by users, hence allowing for additional personalization. Furthermore, the module has the potential to enhance personalization by examining factors such as user preferences, acceptance levels, emotional states, and so forth. We will use our emotion recognition results to improve the personalization of the system and to perform deeper analyses of the data. This endeavor will serve to benefit society at broad and provide support to individuals who suffer from ASD.

VII. ACKNOWLEDGEMENT

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