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Robot-assisted Relaxation Training for Children with Autism Spectrum Disorders

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Abstract**—**Cognitive Behavioral Therapy (CBT) has been proven an effective tool to address anger and anxiety issues in children and adolescents with Autism Spectrum Disorders (ASD). Robot-enhanced therapy has been used in psychosocial and educational interventions for children with ASD with promising results. Whenever CBT-based techniques were incorporated in robot-based interventions, they were mainly performed in group sessions. Objectives: The study's main objective was the implementation and evaluation of the effectiveness of a relaxation training intervention for children with ASD, delivered by the social robot NAO. Methods: 20 children (aged 7–12 years) were randomly assigned to 16 sessions of relaxation training implemented twice a week. Two groups were formed: the NAO group (children participated in individual sessions with the support of NAO) and the control group (children participated in individual sessions with the support of the therapist only). Participants received three different relaxation scenarios of increasing difficulty (a breathing scenario, a progressive muscle relaxation scenario and a body scan medication scenario), as well as related homework sheets for practicing. Pre- and post-intervention assessments were conducted using the Child Behavior Checklist (CBCL) and the Strengths and Difficulties Questionnaire for parents (SDQ-P). Participants were also asked to complete an open-ended questionnaire to evaluate the effectiveness of the training. Parents' satisfaction was evaluated via a questionnaire and children satisfaction was assessed by a thermometer scale. Results: The study supports the use of relaxation training with the NAO robot as instructor for children with ASD. Parents of enrolled children reported high levels of satisfaction and provided positive ratings of the training acceptability. Children in the NAO group presented greater motivation to complete homework and adopt the learned techniques at home. Conclusions: Relaxation training could be effectively integrated in robot-assisted protocols to help children with ASD regulate emotions and develop self-control.

Keywords**—**Autism spectrum disorders, CBT, children relaxation training, robot-assisted therapy.

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I. Introduction

CBT is increasingly being used to treat anxiety and co-occurring emotion dysregulation associated with ASD with promising results [1], [2].

Wood and Gadow estimate that 7% to 57% of children with ASD experience anxiety compared to 2.2% to 27% among the general population [3]. In a randomized clinical trial of 167 children with ASD and maladaptive anxiety, it was observed that CBT designed for children with ASD yielded significantly lower anxiety scores and higher rates of positive treatment response than treatment as usual [4]. Similar findings in youth with high-functioning ASD suggest that CBT demonstrate robust efficacy in reducing anxiety symptomatology [5]. Group CBT interventions specifically designed for children in the autism spectrum were also found effective in decreasing anxiety [6]. Behavioral techniques are widely used in treating anger and challenging behaviors in autism, which are the main reasons for clinical referral [7], [8].

Robot-assisted therapy is a kind of therapy that helps to augment the traditional human therapy and has been used in psychosocial and educational interventions with ASD children [9], [10]. Whenever CBT-based techniques were incorporated in robot-based interventions, they were mainly performed in group sessions [11], [12]. A recent, randomized, controlled trial provided useful information about the application of a robot assisted-CBT intervention that targeted socio-emotional understanding, through a social robot and has shown that robots could be used as effective mediators in robot-assisted CBT protocols [9]. Little is known about the fruitfulness of relaxation training by a robot instructor in helping children with ASD regulate their negative emotions like anxiety and anger and learn to relax. A recent study, that used a robot assistant to facilitate mindfulness training as well as electroencephalogram (EEG) changes to evaluate the outcome, found a significant main effect of time on participants self-reported affect, indicating an improved mood after interaction with the robot [13].

The current study investigated the effectiveness of a self-regulation protocol for children with ASD based on relaxation training delivered by the humanoid NAO robot in individual sessions. The robot-relaxation training protocol was used as an adjunctive intervention, comprising one part of a robot-assisted treatment intervention, in a randomized controlled trial exploring the role of NAO as a therapist assistant [14].

II. Methods and Materials

20 children were randomly assigned to 16 sessions of relaxation training implemented twice a week. Diagnosis was confirmed by a psychiatrist or child-neurologist and all parents provided informed written consent. The method of recruitment is presented analytically in [14].

After satisfaction of the inclusion criteria, children were allocated into two groups: a social robot-assisted therapy group (NAO group) and a therapist only psychosocial intervention group (Control group). Sessions were conducted by a licensed clinical child who received weekly supervisions from the first author. Participants in both groups received the same relaxation training comprised by: a breathing scenario (3 levels), a progressive muscle relaxation scenario (3 levels), a guided imagery scenario (3 levels), and a body scan meditation scenario (2 levels). The instruction was given by the NAO robot in a natural tone while slow tempo background music was playing. Linguistic cues [15] were used by the robot to encourage and reward the child when appropriate. Relaxation related homework sheets were delivered to the child and his/her parents for practicing at home.

Pre- and post-intervention assessments were conducted using the CBCL and the SDQ-P. The CBCL is a parent-report measure of symptomatology, with items rated on a 0-2 Likert scale (0 = "Not True," 1 = "Somewhat or Sometimes True," or 2 = "Very True or Often True"). Four out of the six norm-referenced DSM-Oriented Scales (Affective Problems, Anxiety Problems, Somatic Problems, and Attention Deficit/ Hyperactivity Problems) and the Externalizing scale were used in the current study. The SDQ is composed of 25 items that form four subscales (Emotional Symptoms, Conduct Problems, Hyperactivity, and Peer Problems) composed of 5 items each, with higher scores indicating higher difficulty in the explored areas. SDQ also provides a total score for internalizing and externalizing problems. A subscale of prosocial behavior, the subscale measures the strengths of the child and increasing scores represent higher prosocial behavior. Answer options for each item are: 'Not true' 'Somewhat true' or 'Certainly true', and these are scored 0, 1 or 2, giving a maximum total score of 10. Parents were asked to complete these questionnaires according to their child's age group twice, once at each assessment of the study. Changes in CBCL T-scores between the two time points were compared using paired t-tests.

To evaluate the effectiveness of the relaxation training, a short, open-ended questionnaire (e.g., question: how can you relax yourself, when anxious?) a follow up parent interview and satisfaction sheets (in the form of a questionnaire for parents and in the form of a 0-10 point thermometer for children) were used. The parent's questionnaire included three questions asking parents: a. how often did your child practiced the techniques at home? b. how willing is your child to participate in a similar training? c. how satisfied are you from the relaxation training? Questions were rated in a 10-point Likert scale.

III. Results

20 children with a primary diagnosis of ASD (14 boys and 6 girls) aged between 7 and 12 years (M = 9.9, SD = 1.6) were randomly assigned to either NAO group (10 children) or control group (10 children). During the course of the intervention three children from the control group discontinued the treatment due to SARS-CoV-2 infection and mandatory quarantine; therefore data for 7 children of the control group are presented.

For the NAO group, a significant positive difference was observed in the Anxiety problems subscale [baseline M = 4.50, SD = 2.42 vs end of treatment M = 3.42, SD = 2.38; $t(10) = -2.86$, $p = .015$]. All the other CBCL and SDQ domains did not show significant differences although a decrease in the mean scores was apparent. For the control group, significant positive differences were observed in CBCL total score [baseline M = 59.71, SD = 6.75 vs end of treatment M = 56.00, SD = 5.94; $t(7) = -2.60$, $p = .040$], Affective Problems subscale [baseline M = 5.29, SD = 1.60 vs end of treatment M = 3.86, SD = 1.57; $t(7) = -3.87$, $p = .008$], Deficit/ Hyperactivity subscale [baseline M = 6.29, SD = 3.20 vs end of treatment M = 4.86, SD = 2.67; $t(7) = -2.70$, $p = .035$], and the Internalizing subscale [baseline M = 65.29, SD = 2.62 vs end of treatment M = 60.00, SD = 6.29; $t(7) = 2.82$, $p = .030$]. Positive differences were also confirmed in the SDQ Hyperactivity [baseline M = 6.14, SD = 1.5 vs end of treatment M = 5.14, SD = 1.77; $t(7) = 3.24$, $p = .018$] and SDQ Externalizing subscale [baseline M = 7.57, SD = 2.22 vs end of treatment M = 6.29, SD = 1.97; $t(7) = 2.46$, $p = .049$].

Children's satisfaction found to be similar in both groups. Specifically, NAO group satisfaction (M = 9.61, SD = .96) was not statistically different [$t(17) = -.252$, $p = .80$)] from Control group satisfaction (M = 9.50, SD = .83).

Parents of both groups reported that their children practiced relaxation techniques at home [NAO group (M = 7.60, SD = 1.17) vs Control group (M = 7.00, SD = 2.08); $t(15) = .761$, $\pi = .458$] and were likely to participate in further trainings [(M = 9.10, SD = .73) vs (M = 8.85, SD = 1.67); $t(15) = .409$, $p = .688$]. Overall parental satisfaction found to be high for both groups [NAO group (M = 8.90, SD = .87) vs Control group (M = 8.57, SD = 1.39); $t(15) = .599$, $p = .558$].

NAO group participants' parents in both groups provided positive ratings of intervention acceptability. The NAO group children were more motivated to participate in further relaxation training sessions and were more likely to practice the techniques at home.

To get better insights into the engagement and satisfaction levels qualitative analysis was performed for the open-ended questionnaire and the parent interview (end of treatment). Eleven response categories have emerged after assigning codes to words and phrases in children's responses to the evaluation questions. All children except one described at least one relaxation or stress-reducing activity as a potential way to help themselves feel calmer. Breathing-focused strategies, self-distraction and muscle relaxation techniques were most frequently mentioned for anger and anxiety management in both groups. Regarding anxiety relief, slow breathing was the

most popular answer (total 16 responses), followed by counting down (total 13 responses), deep breathing (total 13 responses) and squeezing the muscles in hands (total 12 responses). The same pattern was observed in anger management; slow breathing (total 16 responses), counting down (total 12 responses), deep breathing (total 13 responses), abbreviated muscle relaxation (total 11 responses). Details are presented in Table I.

TABLE I
CODING OF CHILDREN'S RESPONSES TO THE EVALUATION QUESTIONNAIRE

Response categories	Anxiety management question		Anger management question	
	NAO group (n = 10)	Control group (n = 7)	NAO group (n = 10)	Control group (n = 7)
Slow Breathing	10	6	10	6
Count down slowly from 10 to 0	8	5	7	5
Deep Breathing - Diaphragmatic/"Belly" Breathing	7	5	5	4
Abbreviated muscle relaxation - Squeeze hands/ ball	7	5	6	5
Ask an adult to help	5	3	4	2
Exercise - dance	6	1	2	2
Sensory Awareness- The 5-4-3-2-1 Grounding Technique	4	2	2	1
Request break	4	1	0	0
Read a favorite book	2	1	0	0
Go to "calm-down corner"	2	0	2	1
Use cue cards to remind relaxation techniques	1	1	0	0

Parents were asked to participate in a short follow up interview to provide feedback and reflect upon their child's behavior after the end of the training. Two themes were identified expressing changes in behavioral and emotional domains (see Table II). Only three parents have mentioned limitation of aggressiveness, self-injurious behavior, and repetitive behavior. Parents mainly reported less frequent and intense outbursts (10 parents) and improvement in emotional management in relation to emotional control (8 parents), self-regulation (9 parents), and emotional understanding (7 parents).

TABLE II
EMERGING THEMES AND EXAMPLES FROM PARENTAL INTERVIEW

Themes	Sub-themes	Quotations
Behavioral aspects	Outbursts	"Child behaved appropriately in the supermarket, whereas she used to scream and demand more candies"
	Aggressiveness	"Child accepted losing and did not attack his brother"
	Self-injurious behavior	"Child hasn't bitten his hand for the last two weeks. Instead, he was squeezing his stress ball"
	Repetitive behavior	"Child counted backwards and said: by zero I am going to relax and stop hand-flapping"
Emotional aspects	Emotional control	"Child countdown and repeated robot-instructions like -I am trying to relax now"
	Self-regulation	"Child was practicing slow breathing whenever anxious at school"
	Emotional understanding	"For the first time, child asked me -are you angry" now?"

IV. DISCUSSION

This study explored the efficiency of robot-assisted relaxation training for children with ASD. It was hypothesized that such an intervention protocol could help children deal with anxiety and anger symptoms.

To explore the results from the interaction with NAO, quantitative and qualitative analyses were provided. A positive significant effect was found in the anxiety subscale of CBCL for the NAO group. This result is in line with [16] who used breathing exercises in a CBT robot intervention program for anger management and self-control with positive results. On the other hand, a Yale University study that examined the interaction with a robot after completing a stressful task, observed positive results in mood increase in comparison with the control group but no improvement in negative mood and anxiety [17]. Although changes were not significant for the rest of the CBCL and SDQ subscales, in the robot group, this is expected, as relaxation training mainly targets anxiety symptoms.

Improvement in the control group was expressed by better scores in several subscales, as expected, since robot-based interventions lack the autonomy, flexibility and the variety of human therapists' intervention.

Both groups proved to benefit from the relaxation training with parents reporting higher emotional control and self-regulation, shortened and less intense outbursts, and higher emotional understanding in the follow-up interviews. Parents in both groups provided positive ratings of intervention acceptability. The NAO group children were more motivated to participate in further relaxation training sessions and were more likely to practice the techniques at home.

Results suggest that relaxation training can be offered by social robots in robot-assisted interventions to teach children self-regulation and help reduce anxiety-related symptoms. This study represents an additional step to the design of robot-assisted interventions but further work is needed to confirm and extend the findings on the efficiency of relaxation training provided by social robots.

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