Impact of Humanoid Social Robots on Treatment of a Pair of Iranian Autistic Twins

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Abstract. In recent years robots have been increasingly used in autism research. In this paper the effects of robot-assisted interventions on two seven year old autistic twin brothers, one of whom is high-functioning and the other low-functioning, are explored. To this end, 12 sessions of therapeutic scenarios were designed and presented to the autistic twin subjects in the presence of two robots, a therapist and their parents in individual and group modes. The results showed great potential benefits from using robots in group therapeutic games in both high- and low- functioning autistic children, such as improvement in imitation and joint attention skills for both brothers, as well as communication with each other. The results also indicated a decrease of stereotyped behaviors in the low-functioning brother, and improvement in social and cognitive skills in the high-functioning brother.

Keywords: Humanoid robot · Joint attention · High- and low-functioning autism · Autistic twin · Imitation

1 Introduction

Humanoid robots can be used as a powerful tool to improve social and motor skills as well as joint attention in autistic children [1, 2]. Individuals with autism usually shy away from social interactions and communications and are impaired in showing proper reactions to real world events [3]. To this date, a wide range of studies have been done on the application of robots in autism treatment (especially on high-function autistic children) to improve imitation, joint attention, and social interaction skills of autistic children [4-13]. Although there has been research on autistic twins and the relative contributions of genetics and environment to autism spectrum disorders [14-15], to the best of our knowledge using humanoid robots specifically in

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the treatment of twins with autism has not been reported. What makes this study different is that it focuses on the robot-assisted interventions of seven-year old autistic twins, one of whom is high-functioning and the other low-functioning. The two participants were fraternal twin brothers. Besides improving motor and social interaction skills of these two subjects with each other and with their parents, the main purpose of this study was to investigate how the effect of robot-assisted autism therapy differs for high-and low-functioning autistic children.

2 Research Methodology

2.1 Participants

Our subjects were seven-year old fraternal autistic twins. Both were male and diagnosed with autism spectrum disorders; one is High-functioning with hyperactivity (called S1-A) and the other is Low-functioning (called S2-I). The advantage of investigating twins in comparison to other cases is factors such as parents, food, clothes, and education have been controlled, a difficult task in general research. S1-A is a high-functioning autistic boy with hyperactivity and mild verbal skills. Eye-contact avoidance also existed since an early age. At the age of seven his parents were informed that S1-A was a high-functioning autistic child. S2-I is a low-functioning autistic child with poor verbal skills. S2-I's autism is more severe than his twin brother and he usually engages in repetitive, non-purposeful, and stereotyped behaviors such as fluttering fingers.

2.2 Intervention Sessions

The intervention sessions included various games in order to teach individual and group sport skills (Robot-Patient and Robot-Patient-Brother/Parent) and engage them in different imitation and joint attention situations. The intervention sessions were run on the autistic twins in the presence of the Humanoid Robot(s), therapist, robot operator, and their parents in a fairly friendly environment. Our study approach was a single subject design using Wizard of Oz style robot control. Intervention scenarios were designed based on clinical psychologists' explanations of psychology theories, shaping behaviors therapy, and Applied Behavior Analysis (ABA) models run in autism treatment centers. The pre-designed scenarios were conducted in 12 thirty-minute sessions held twice a week for 6 weeks at the Social Robotics Laboratory at Sharif University of Technology.

2.3 Set-up of the Study

The room size was $5\times5\times3$ m^3. The set-up of our study consisted of two humanoid robots, Microsoft Kinect sensor, video-projector, two laptops, chairs, a whiteboard, and two cameras for filming the sessions. Child-Robot interaction was structured and preset following pre-defined purposes. The scenario instructions were described by

the robot and/or the therapist. The parents of the twin subjects voluntarily took part in our research and they did not pay nor were they paid for the intervention sessions. A pledge was signed by the researchers and parents before the first session in order to maintain moral obligations.

2.4 Humanoid Robots

The humanoid robots used in our educational-therapeutic programs were the NAO-H21 made by Aldebaran Company [16] with 21 degrees-of-freedom (DOFs), and the Alice-R50 made by Robokind Company [17] with 32 degrees of freedom. To be used in the Iranian context, these robots were renamed "Nima" and "Mina", respectively. These two robots have the necessary capabilities needed for our designed intervention scenarios. Moreover, other researchers around the world have also used these commercial robots in autism research [4, 8, and 12]. Our concentration was on using the Nima robot; however, we also used the Mina robot because: a) it has 11 DOFs in the face and is capable of showing different facial expressions, and b) we wanted to explore if changing the robot effected the children's performance.

2.5 Therapeutic Games

A variety of therapeutic games were developed based on the children's autistic impairments in order to answer our research questions. These games concentrated on improving the children's imitation, joint attention, social skills, eye-contact, and turn-taking. In each session the twins participated in several of the games in different modes; Robot-Child or Robot-Child-Brother/Parent/Therapist interactions. Table 1 presents the list of games. The schedule of intervention sessions is presented in Table 2.

2.6 Assessment Tools

The four main instruments used to measure the effects of the interventions in this study are as follows:

Gilliam Autism Rating Scale (GARS): One of the most well-known autism assessment tools is the Gilliam Autism Rating Scale (GARS). This questionnaire is a valid tool developed by Gilliam in the1990s [18] to help estimate autism severity. GARS is divided into four different subscales: Stereotyped Behaviors, Communication, Social Interactions, and Developmental Disturbances [19]. GARS has been used for 100 autistic children in Iran and the Cronbach's alpha for its four subscales and the overall test are 0.74, 0.92, 0.73, 0.80, and 0.89, respectively [20]. The GARS questionnaire was filled in by the children's parents one week before and one week after the robot-assisted program.

Table 1. List of Therapeutic Games

#	Games	Modes	Main Purposes of the Game
1	Teaching imitation and motor skills by robot to child/children through individual/group exercise and dances	Robot-Child Robot-Child-Brother/Parent	Improve imitation, Improve motor and social Skills, Dyadic/Triadic interactions, Turn-taking games
2	Real-time Imitation of Robot by child in upper body movements	Robot-Child	Draw attention of child to child to robot and therapist, Child can see his movements reflected in another person
3	Tele-operating humanoid robots' heads and hands using a 6-DOFs Haptic Phantom-Omni robot as a remote controller	Robot-Child	Empowering children and therapist to move the robots' joints arbitrary, Dyadic/triadic interactions, Turn-Taking games
4	Kinect-based Recognition Game: Classification of animals and fruit by pointing to different baskets on the screen	Robot-Child Robot-Child-Parent	Classification, Joint attention, Pointing, Gaze-shifting
5	Playing a developed Kinect based virtual xylophone on the screen	Child-Parent/Therapist robot applaud child for a task correctly done	Improve child's hand imitation skills, Joint attention, and child's visual pursuit
6	Playing a real xylophone in a Robot-Child turn-taking game	Robot-Child	Imitation of Robot by Child and vice versa, Joint attention, Turn-taking, Improve in cognitive skills, Colors recognition, Hand-eye coordination

Quantitative Content Analysis of Intervention Video Records: Quantitative content analysis is a powerful tool to analyze written texts, videos or other media [21, 22]. To analyze the autistic twin's behaviors during the sessions, intervention video records have been observed and rated by two psychologists. The seven major items (some with different sub-items) rated by the psychologists consisted of: 1) Imitation, 2) Joint attention, pointing and gaze shifting, 3) Maladaptive behaviors, 4) Verbal and non-verbal communications, 5) Instruction perception and cooperation, 6) Intercommunity, and 7) Interest in and enjoying individual/group games. Although quantitative content analysis is usually time-consuming and costly, it gave us worthwhile results. Two psychologists separately observed and rated the behaviors of each child in all of intervention sessions. Due to the fact that the children's mother may not have been able to be absolutely objective in filling in the questionnaires, the content analysis of the video records and the interviews are of great importance.

Human's Assessment of Behaviors: In order to see the effect of the robot intervention on autistic behavior in the boys real life, a child clinical psychologist assessed both of the children's abilities one week before and one week after the intervention sessions.

Table 2. Intervention Session Schedule; the letters describe R: Robot, P: Parent, T: Therapist.

Session	Game#/Mode	Participants in Game					Description
		S1	S2	R	P	T	
1	Orientation Session						Robots showed their capabilities
2	#4/ Robot-Child						S2-I did not take part in the game
3	#2/ Robot-Child						
	#1/ Robot-Child						Interestingly, using the Mina robot did not affect the children's performance.
	#3/ Robot-Child						
4	#5/ Child-Therapist						Robot applauded them for the correct task. S1 intervened in his twin's game
5	#6/ Robot-Child						
6	#3/ Robot-Child						Game #3 was selected for session six at the request of the twins
7	#1/ Robot-Child-Child						Difficulty Level of the Tasks: Easy
8	#1/ Robot-Child-Child						Difficulty Level of the Tasks: Medium
9	#1/ Robot-Child-Parent						S2-I was absent in this session
10	#1/ Robot-Child-Child						Difficulty Level of the Tasks: Hard
11	#1/ Robot-Child-Parent						Difficulty Level of the Tasks: Medium
	#4/ Child-Parent						
	#4/ Robot-Child						
12	Farewell						

Interview with Parents: Each child had the potential to show novel social interactions in his real life which might not have been observed during our limited sessions. However, the parents spent most of their time with the children and hence could inform us if any behavior changes occurred.

3 Results and Discussions

Figures 1-4 show some intervention session snapshots, Social Robotics Lab (SUT).

Different measurement instruments were used to measure the effects of the interventions. The GARS questionnaire was completed twice by the subjects' parents: one week before the program started, and one week after the completion of the interventions. Different skills of the two participants were assessed by a child clinical psychologist one week before and one week after the robot assisted treatment. Furthermore, Quantitative Content Analysis of the video records of the sessions was done by two additional child clinical psychologists from CTAD.

Fig. 1. Imitation of the robot by the autistic twins in a group game- Game#1.

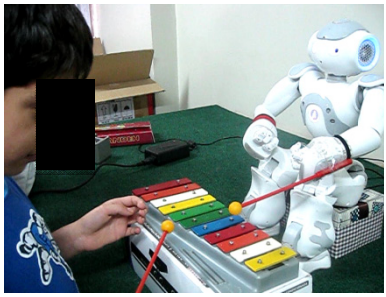

Fig. 2. Playing the xylophone in a turn-taking game- Game#6.

Fig. 3. Teleoperating Robots using the Haptic Phantom Omni robot- Game#3.

Fig. 4. Animal and friut recognition game in Child-Parent mode, Game#4.

3.1 Quantitative Content Analysis

Based on the video records the most important findings are as follows: Both subjects showed great improvement in terms of joint attention, pointing, and gaze shifting. It is important to note that the twin brothers had both received previous ABA treatments for 6 months in an autism center and also had some occupational and verbal communication therapy. Accordingly, their imitation of the robot was quite acceptable.

One of the most significant improvements in S2-I was the decrease of his autistic and maladaptive behaviors such as stereotyped behavior (specially fluttering fingers in front of the face and staring), meaningless repetition of a word/words and echo, ecstasy and inattention to the group, and engaging in solitary interests and hobbies. Additionally, S1-A showed great improvement in verbal communication, social participation, and enjoying group games.

In general, what stands out in the results obtained from the quantitative content analysis of the video records is S1-A's great improvement in social interactions, and S2-I's decrease of autistic detrimental behaviors. In other words, it can be stated that robotic group games have the potential to improve social behaviors and interactions in high-functioning autistic children, and lower the amount of stereotyped and detrimental behaviors in the low-functioning autistic children.

3.2 GARS

The subjects' mother was asked to fill in the GARS one week before and one week after the program. It should be noted that higher scores indicate higher severity of autism. The scores are presented in Fig. 5.

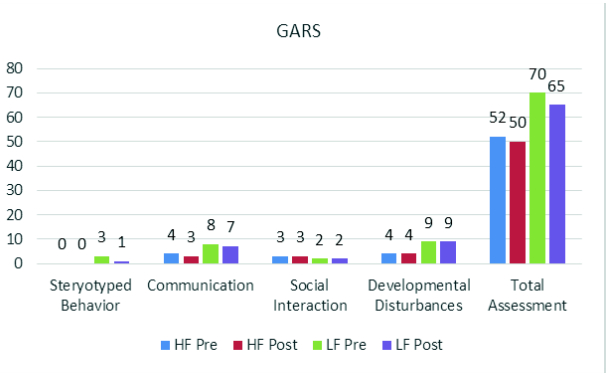

Fig. 5. GARS subscales and total scores for S1-A (HF) and S2-I (LF) in Pre- and Post- tests.

As the GARS scores indicate, S1-A did not experience a significant change in terms of the factors assessed through this questionnaire. However, he showed improvement in communication in line with the findings of the quantitative content analysis of the video records. S2-I showed more improvement especially in terms of decreased stereotyped behaviors and better social communication. This also supports the results obtained from the video records.

3.3 Human Assessment

The twin brothers were assessed by a clinical child psychologist one week before and one week after the program. The criteria for this assessment consisted of more than 25 items on self-help skills, social interaction, verbal communications, motor skills, and cognitive skills. Based on clinical observation reports presented by the assessor child clinical psychologist, S1-A showed better progress in verbal communications and joint attention skills than in other tested skills. His main difficulties were in high level cognitive skills. According to the psychologist's qualitative report, S2-I made progress in instruction perceptions and cooperation, imitation and motor skills. However, she reported that S2-I's major defects were still mental skills and verbal communications in comparison to his past.

3.4 Interview with Parents

As mentioned before, we had an interview with the twin's parents after our last clinical session. The most interesting parts of the interview are quoted as follows:

> "In contrary to their ABA classes, our kids showed inexplicable interest in taking part in imitation and turn-taking games and they were super happy when leaving intervention sessions. For the first time since their birth, we have seen the twin brothers playing a meaningful turn-taking game together with their table-soccer at home. They never understood that the robots' actions occurred because of commands sent by an operator to the robots."

The mother stated,

> "We believed that robotic clinical intervention would have a positive effect on our children's social interaction and their communication toward each other during these two months; however, we did not expect a miracle in their progress! Bringing my children to this different intervention program, I think I am doing my mother's duties better than the past."

The overall findings of this study showed that using robots in treatment of children with autism is potentially quite effective for both high- and low-functioning children with autism. However, the effects seem to be different for autistic children from different points on the autism spectrum. Low-functioning autistic children have more potential for improvement in imitation and joint attention skills with robot assisted therapy programs. This research was a pilot study and based on a single subject design experiment; therefore, generalizing the findings would require further research in larger-scale groups.

4 Conclusion

The results indicated that the high-functioning subject's Social Skills improved due to the two and a half month robotic treatment. In the case of the low-functioning subject, no significant improvement was observed in terms of his Social Interaction and Developmental Disturbances. His Stereotyped Behaviors, however, decreased during the course of the program. Moreover, both participants seemed to have better Communication after the treatment. As the subjects' mother claimed, for the first time in seven years she had found the twin brothers playing a meaningful game together at home. This could be due to the robot-child-brother/parent group games the subjects were involved in. Our observations showed that robot-assisted treatment has great potential to lower the severity of autism in the low-functioning subjects and improve the social skills in the high-functioning subjects. In other words, the robot-assisted clinical interventions seemed to be helpful both for low- and high-functioning children with autism. The progress rate, however, turned out to be much more significant in children with high-functioning autism. It should be noted that because of the small number of studied participants in single subject design studies, there are no strong claims on generalizing the findings to other autistic children; however, we focused deeply on

the twins' behaviors during our robotic-assisted interactions to evaluate the effectiveness of the various scenarios on the studied subjects. As one of the pioneers in using this technology in Iran [23-29], the social robotics research group has high hopes that the findings of our studies can facilitate autism therapy in Iran.

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