The 23rd IEEE International Symposium on Robot and
Human Interactive Communication
August 25-29, 2014. Edinburgh, Scotland, UK,

A Robotic Treatment Approach to promote Social Interaction Skills for Children with Autism Spectrum Disorders

Sang-Seok Yun, Sung-Kee Park, and JongSuk Choi

Abstract—**In this paper, we propose with a robot-assisted behavioral intervention system to easily improve children's social capability. In particular, the system for children with autism spectrum disorders (ASD) is basically achieved through the discrete trial teaching (DTT) protocol with three task modes of therapy, encouragement, and pause in social training scenarios. In child-robot interaction architecture, the robot firstly offers therapeutic training elements of mutual greeting and interplay game, and evaluates the level of children's reactivity by recognition modules for frontal face and touch features. Thence, the system in the decision-making process determines the task mode to perform subsequent action by grasping behavioral state of the children, and then it copes with individual response appropriately by using the robotic stimuli with the combination of kinesic acts and displayable contents. From the experiments of clinical trials with children with non-ASD and ASD in each robotic stimulus, the system showed the potential to increase their attention and activeness for social training, and we believe that the proposed system has some positive effect on developing children's social skills.**

I. Introduction

As social creatures, children with autism spectrum disorders (ASD) have lacks of primitive social skills for self-initiated interaction, turn-taking, emotion recognition, joint attention and even eye-contact compared to typically developing children [1]. According to the behavior characteristic analysis in social sciences, children with ASD tend to avoid eye-contact distinguishably, and they usually sustain unusual or repetitive play with inappropriate response. These features have difficulties in social activities in early childhood and even in adulthood as a member of social group. For those reasons, it will be more difficult for them to interact with people and engage in social activities unless appropriate treatments are supplied in a timely manner [2].

With respect to these problems, interactive robots in recent studies are a strong candidate to elicit high interest and active engagement in children with ASD by its appearance and behavioral features. Furthermore, the robot has the strength point of facilitating social skills training of them as a clinical mediator [3, 4]. The most representative example for the use of interactive robots in the socialization of children with autism is the Aurora project that was focused on the advantage of enhancing primitive social skills with simple turn-taking tasks by comparison with the virtual environments [5]. In the project study, the robot interacting between adults and children with autism showed the results that autistic children shared their interaction experiences with their parents as one of the interesting mediator [6]. With inspiration from the psychological study, cute robots named Infanoid and Keepon, which has psychological models of human social intelligence to analyze social development in children when they interact with these robots, were also a good case study to lead a seamless interaction with children with ASD in a natural conversation [7, 8]. In addition, as an imitation agent, the robot evoked more appropriate social behaviors from children with ASD in the HRI intervention designs in order to facilitate human social behavior [9]. In the current trends, robot-assisted therapeutic interventions have been proposed as clinical tools to easily establish social interaction with the children, A case study showed some possibility that children with ASD is able to interact with the robot, and it showed that therapy using robot can encourage the children in deviating isolation from others and induce them to come up with sharing their mind [10]. Above all, robotic treatments are required to suitably perform robot behaviors from interpreting interaction signals of the children in order to induce the attentional focus and provoke social behaviors of them. In particular, attention among primitive social skills is an important factor in the robotic autism treatments, and the reliable analysis of child's facial gaze is also a significant cue in the child-root interaction to analyze degree of concerning of children's interest from the viewpoint of cognitive science. One study that the robot detects intentions of children with ASD through tracking their gaze showed to improve the ability of attention related to the joint-attention [11]. As robot control architecture targeted at children with ASD, the Robot in another novel research reduced the negative avoidance of children by others as improving their attention through the robot's encouragement, and thus leading to better communicate with others [12].

Based on these finding, the critical issue in the child-robot interaction is about how to determine the behavioral response of children and provide the appropriate correspondence for children's response instantly. From here, the main role of interactive robots on the therapeutic intervention is to retain its autonomy in training process of social interaction skills. Furthermore, an integrated implementation of the interaction channel with robotic features or special functions can be key elements in the facilitation of specific social skills of children with ASD.

*This work was supported by the KIST Institutional Program (No. 2E24722).

Sang-Seok Yun is with the Center for Bionics, Korea Institute of Science and Technology (KIST), Seoul 136-791, Republic of Korea (e-mail: yssmecha@ gmail.com).

Sung-Kee Park is with the Center for Bionics, Korea Institute of Science and Technology (KIST), Seoul 136-791, Republic of Korea (e-mail:skee@kist.re.kr).

JongSuk Choi is with the Center for Bionics, Korea Institute of Science and Technology (KIST), Seoul 136-791, Republic of Korea (Corresponding author to provide phone: +82-10-2958-6815; e-mail: cjs@kist.re.kr).

Accordingly, we propose the robot system for autism treatments supporting appropriate correspondence according to the behavioral response of children, as intervention system. Based on the interaction process in therapeutic protocol, the robot system in the interaction architecture estimates the level of reactivity for children's intended behavior by recognition modules, configures its behavioral tasks in each response state model of therapy with rewards, encouragement, and pause through an intimate appearance, kinesic acts, and displayable training contents, and performs social training scenarios including primitive eye-contact and touch game to the children. The evaluation methods of the proposed system's effectiveness consist of two properties of comparative analysis of behavioral responses of children and survey assessment targeted at children's caregivers for responding behavior in robotic treatments.

This paper is organized as follows. Chapter 2 explains the outline of robotic system for autism treatments. In chapter 3, experimental methods and its results in the therapy session are shown. In chapter 4, the conclusion and future works are discussed.

II. Robot System for Autism Treatments

A. Intervention Protocol Design

To provide less anxious and effective social skills to the children, we designed robot-assisted behavioral treatments system performing social training scenarios in accordance with discrete trial teaching (DTT) protocol, which is based on the science of applied behavioral analysis (ABA) [13] and is the most well-known method for individualizing and simplifying instruction to enhance children's learning [14-16].

The protocol basically consists of an antecedent stimulus, an acceptable response, and a consequence stimulus. In addition, the training process to implement the protocol can be briefly explained as follows. At first, the robot provides the discriminative stimulus to children with ASD by using social training elements. The training elements can be basically made up of eye-to-eye gaze interaction, joint attention, imitation, touch game, call response, and pretend play. Since then, the robot analyzes human response by interpreting behavior signals. The response is divided into positive, negative, and non-response. Afterwards, the robot performs to select appropriate actions among pre-allocated consequence stimuli with robotic features according to the disposition to respond.

B. Interaction Architecture

From the intervention protocol design, we configured the interaction architecture with three modules of response perception, training mode, and robotic stimuli as shown in Fig. 1.

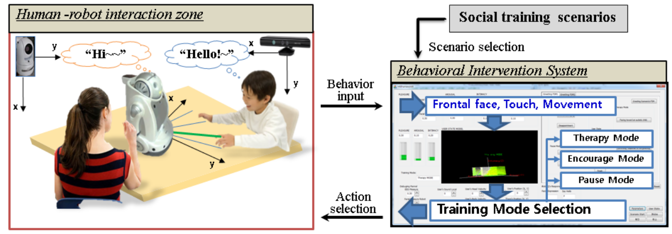


Figure 1. An overview of robot-assisted therapeutic intervention system

The robot system is firstly required to perceptual capability of recognizing the intended responses of children. By frontal face classifier [17], the system can detect the frontal face of them, which is effectively similar to eye-contact detection, from the RGB camera located on the robot head. Then, the system can recognize tactile responses of children through touch sensors attached on the robot body. And then, it estimates the body position and movement of each subject by measuring motion region information of moving objects from the RGB-D stream of a Kinect sensor in background subtraction technologies [18]. From the location data of each subject in the global coordinates, the model can also calculate a physical distance between subjects to estimate intimacy level.

For the control of robotic behavior, the computational model in the architecture basically decides one of the pre-allocated task executions with three modes of *therapy*, *encouragement*, and *pause* by grasping the response state of children. If the children positively respond to the request of social training, the model would sustain the therapy mode, and provide songs or complimentary remarks to them as a reward. Otherwise, it enters into the encouragement mode to cause them to induce the positive response. If the children show the continued negative or non-response without focusing on the request, the robot finally would get to become in the pause mode to stop its behavior for a period of time in the therapy session.

After training mode selection, it finally generates commands to accomplish appropriate stimuli with robot behavior in social training scenarios. Thus, such interaction architecture performs the training process of therapeutic interventions in which children with ASD could repeatedly practice a social interchange or behavior. Accordingly, it can be assured that the robotic treatments are able to lead children's attention and stir them up to deviate from isolation from other social members.

C. Robotic Stimuli

To induce the attentive focus on robot behaviors and sustain positive reactivity from children with ASD, we utilized a mobile humanoid robot iRobi, which is developed in the Yujin Robotics Co. Ltd. [19], as shown in Fig. 2.

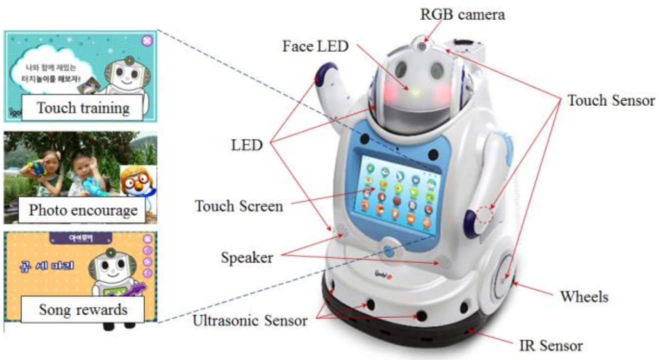


Figure 2. Robotic specification with kinesic acts and displayable contents

iRobi actually has an advantage of appealing appearance with kinesic acts which have behavioral elements of facial expressions, gesture and dance routine, speech acts with lip-sync by face LED, gaze behavior, and emotion expressions with LED blinking. On the other hand, displayable contents on the Touch screen have potential benefits that can express the implicit meaning or emotion, keep the focus on interaction status, and provide a variety of children's songs and a dedicated speech-generation as an augmentative and alternative communication (AAC) [20]. Thus, to make attentional human-robot interaction, we divided expression parts of the robot into three types of kinesic acts (type K), displayable contents (type D), and a combination of both (type KD) at each different task mode.

TABLE I. ROBOTIC STIMULI IN EACH BEHAVIOR MODE

Robotic Stimuli	Behavior Mode	
	Therapy	*Encouragement*
Kinesic behaviors (Type K)	- Nodding - Raising hands - Dance routine	- Waving - Yawing from side to side - Blinking LEDs
Displayable contents (Type D)	- Training state images - Animation clips	- Their own pictures - Family pictures - Famous cartoon character images
Combination (Type KD)	- Both	- Both

As shown in Table I. the robot provides a variety of attributes of the designated type by each task mode in the pre-configured robotic stimuli in order to provide the best interesting elements to children with ASD.

D. Social Training Scenario

The training scenario of social interaction skills consists of two elements of eye-contact on mutual greeting and body-touch game in the triadic interaction of a child, a therapist, and a robot. To reduce the operational burden of the therapist and focus on their therapeutic service, the robot controller displaying its task status on the GUI was applied to the training scenario as a playmate (see Fig. 3).

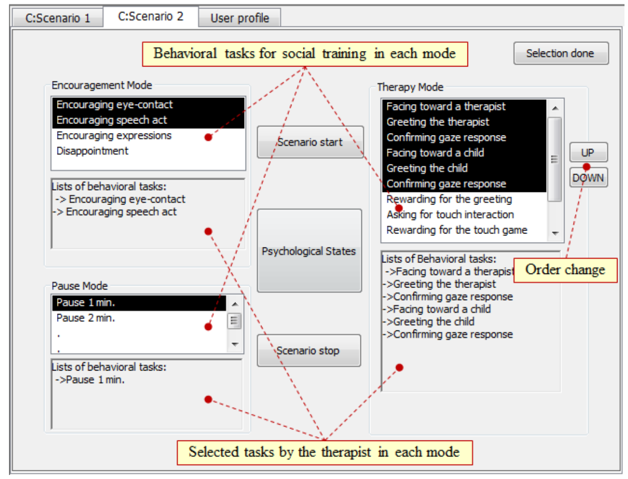
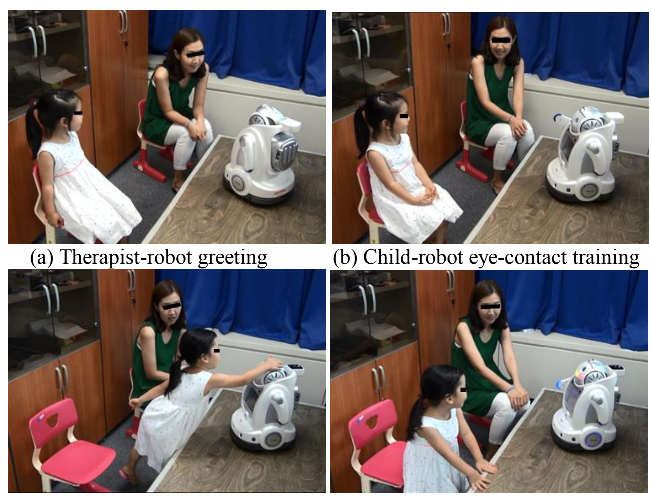


Figure 3. A GUI of social training scenarios for eye contact and touch

According to the intervention protocol design the interactive robot in the process of training scenarios firstly forms a kinship with a therapist in order to guide the child's imitation while performing mutual greeting with exaggerated expressions. Then, the robot moves toward a child and requests to respond two training elements with eye contact and body touch interaction in each step of the behavior mode in types of robotic stimuli. Afterwards, the robot offers a reward for positive response. Otherwise, it provides an encouragement or a pause for negative response. Figure 4 shows experimental scenes of the actual training process in therapy session.



(a) Therapist-robot greeting (b) Child-robot eye-contact training

(c) Body touch training (d) Song rewards

Figure 4. Experimental scenes of the social training process

III. EXPERIMENTS

A. Participants

As a case study, six children aged 36 to 60 months (n=6; 1 male and 2 females in non-ASD group; 2 males and 1 female in ASD group) participated in the experiments of social training. For ASD group, we particularly selected the children who scarcely make eye-contact with other persons according to the therapist's diagnostic observation.

B. Evaluation Method

The training scenarios of social interaction skills were performed on six trials through each different type of robotic stimuli. In the therapy session, we used two standards to validate the usefulness of the robot-assisted behavioral intervention system and each type of robotic stimuli.

The one is to analyze the quantitative extent for children's reaction extent, which is defined to positive response ratio and reaction time in each training element with different types of robotic stimuli and different groups, as a measure about the degree of interest.

Another one is to evaluate the children's attitude toward social training by the questionnaire survey after the experiments. It can estimate the effect of child-robot interaction by using the proposed robotic treatment approach.

C. Clinical Results

In the experiments of each eye-contact and body-touch request, children with ASD showed the more lagging response after referring to the therapist's behavior compared to children with non-ASD. As shown in Table II, there is a meaningful gap between two groups because children with ASD responded after conducting individual repetitive behaviors, and even they did not respond to the request occasionally. However, the important point is the fact that children with ASD responded to the robot's request and even they showed the spontaneous gaze response. Furthermore, the reactivity difference (22%p) between two groups can partly stand for the degree of impairment of children.

TABLE II. COMPARISON RESULTS OF EACH GROUP'S RESPONSE

Division	Attributes	Average		Difference
		Non-ASD	ASD	
Gaze	Response time	0.34s	1.1s	15.2%p
	Gaze ratio	66.3%	46.6%	19.7%p
Touch game	Response time	2.2s	3.5s	13.0%p
	Touch ratio	90.7%	50.6%	40.1%p

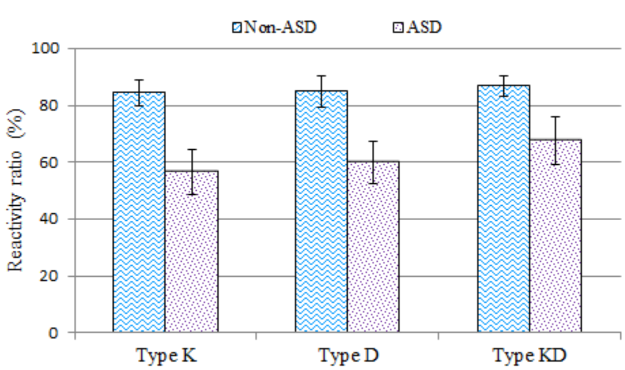


Figure 5. Analysis results of children's eye-contact response

Figure 5 show the experimental results of reactivity ratio in terms of robotic stimuli. For the clinical trials, type KD showed high performance results rather than other types in both groups. In particular, type KD in ASD group (68%) increased a positive reactivity ratio of ≥8%p at an average level compared to type K and D. As a result, we confirmed the fact that a combination of type K and D can show a synergy effect of increasing attention and concentration in children with ASD.

For a child-therapist interaction after performing the child-robot interaction, two out of three children with ASD successfully looked at the therapist at the end. From these results, we assure that it is attributable to the positive effect of social training by interactive robots.

As a second measure, an observer rating about the children's attitude after clinical trials was conducted by children's mothers. The questionnaire was made up of five items with social skills, pleasure, activeness, interest, and positiveness, and each item is on a seven point Likert scale ranging from '*strongly disagree*' to '*strongly agree*'.

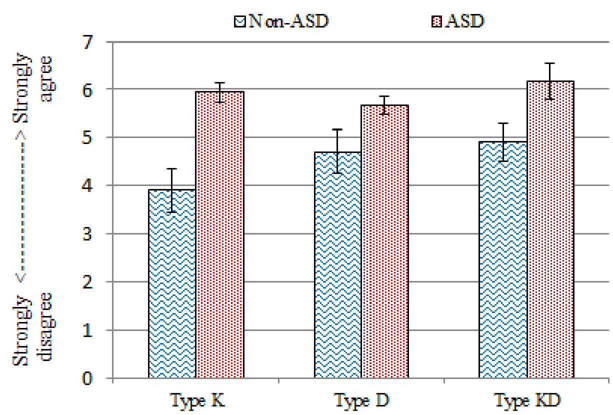


Figure 6. User evaluation for social training scenarios

In the Fig. 6, type KD in both groups showed a high level of satisfaction. For the group comparison, ASD group (5.92) generally got high marks of 32%p compared to non-ASD group (4.5). The absolute ratings may not have a big statistical meaning due to the small sample size. However, it can be assured that the proposed treatments have a competitive advantage in improving social skills of children with ASD from the clinical results.

IV. CONCLUSION

In this research, we proposed a robot-assisted therapeutic intervention system developing social behavior of children with ASD. Based on the well-known DTT protocol, the in interaction architecture supporting the robotic treatments was basically configured to cope with children's responses suitably. Thence, the robot system in the proposed architecture estimated reliable behavioral state of the children by using recognition modules, showed the reasonable decision-making by interpreting acceptable response, and expressed robotic stimuli to the in accordance with the DTT protocol. In addition, the system can provoke children with ASD to be interested in the training scenario and get active attitude by repetitive training. In the clinical trials, participants actually showed much greater concentration to the training requests of eye contact and body touch. Furthermore, by both quantitatively comparative analysis and survey evaluation in terms of type (K, D, and KD) and group (Non-ASD and ASD), we verified the possibility that the robot-assisted intervention system can be effectual means to develop social skills of children with ASD in controlled circumstances.

Thus, as the future work, the proposed architecture will be applied to additional social training programs such as joint attention and call response, and we are planning to have an evidence-based comparative analysis on detailed training programs in clinical trials with the large scaled sample size in order to enhance objectivity for facilitating social skills of the children.

ACKNOWLEDGMENT

We are grateful to Dr. Hee Jeong Yoo, Gui Young Bong, Jung Hyun Lee, Ju Han Yoo for their assistance on clinical trials with insightful discussions.

REFERENCES

[1] D. A. Allen, “Autistic spectrum disorders: clinical presentation in preschool children,” *Journal of Child Neurology*, vol. 3, pp. 48-56, 1988.

[2] T. Charman, J. Swettenham, S. Baron-Cohen, A. Cox, G. Baird, and A. Drew, “Infants with autism: an investigation of empathy, pretend play, joint attention, and imitation,” *Developmental Psychology*, vol. 33(5), pp. 781-789, Sep 1997.

[3] J. J. Diehl, L. M. Schmitt, M. Villano, and C. R. Crowell, “The clinical use of robots for individuals with autism spectrum disorders: a critical review,” *Research in Autism Spectrum Disorders*, vol. 6, pp. 249-262, 2012.

[4] B. Scassellati, H. Admoni, and M. Mataric, “Robots for use in autism research,” *Annual Review of Biomedical Engineering*, vol. 14, pp. 275-294, 2012.

[5] K. Dautenhahn and I. Werry, “Towards interactive robots in autism therapy: Background, motivation and challenges,” *Pragmatics & Cognition*, vol. 12, pp. 1-35, 2004.

[6] B. Robins, K. Dautenhahn, T. Boekhorst, and A. Billard, “Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills?,” *Univers. Access Inf. Soc.*, vol. 4, pp. 105-120, 2005.

[7] H. Kozima and C. Nakagawa, “Interactive robots as facilitators of children’s social development,” *Mobile Robots Towards New Applications*, pp. 314-5, 2006.

[8] H. Kozima, C. Nakagawa, and Y. Yasuda, “Interactive robots for communication-care: A case-study in autism therapy,” in *Proc. IEEE Int. Symp. on Robot and Human Interact. Comm.* (*RO-MAN 2005*), pp. 341-346, 2005.

[9] A. Duquette, F. Michaud, and H. Mercier, “Exploring the use of a mobile robot as an imitation agent with children with low-functioning autism,” *Autonomous Robots*, vol. 24(2), pp. 147-157, 2007.

[10] D. J. Feil-Seifer and M. J. Mataric, “Toward socially assistive robotics for augmenting interventions for children with autism spectrum disorder s,” in *Proc. Int. Symp. on Experimental Robotics* (*ISER 2008*), pp. 201-210, July 2008.

[11] P. De Silva, K. Tadano, A. Saito, S. G. Lambacher, and M. Higashi, “The development of an assistive robot for improving the joint attention of autistic children,” in *Proc. Int. Conf. on Rehabilitation Robotics* (*ICORR 2009*), pp. 694-700, 2009.

[12] D. Feil-Seifer and M. J. Mataric, “B3IA: A control architecture for autonomous robot-assisted behavior intervention for children with Autism Spectrum Disorders,” in *Proc. IEEE Int. Symp.on Robot and Human Interact. Comm.* (*RO-MAN 2008*), pp. 328-333, 2008.

[13] O. I. Lovaas, “Behavioral treatment and normal educational and intellectual functioning in young autistic children,” Journal of Consulting and Clinical Psychology, vol. 55(1), pp. 3-9, 1987.

[14] T. Smith, “Discrete trial training in the treatment of autism,” *Focus on autism and other developmental disabilities*, vol. 16, issue 2, pp. 86-92, 2001.

[15] R. L. Simpson, S. R. de Boer-Ott, D. Griswold, B. S, Myles, S. E. Byrd, J. Ganz, K. T. Cook, K. L. Otten. J. Ben-Arish, S. A. Kline, L. G. Adams, *Autism Spectrum Disroders: Interventions and Treatments for Children and Youth*. Thousand Oaks, CA: Corwin Press, 2005.

[16] L. A. Vismara and S.J. Rogers, “Behavioral treatments in autism spectrum disorder: what do we know?,” *Annual Review of Clinical Psychology*, vol. 6, pp. 447-468, 2010.

[17] P. Viola and M. Jones, “Robust real-time face detection,” *Int. J. Computer Vision*, vol. 57(2), pp. 137-154, 2004.

[18] Z. Zivkovic, “Improved adaptive Gaussian mixture model for background subtraction,” in *Proc. Int. Conf. Pattern Recognition*, vol. 2, pp. 28-31, 2004.

[19] iRobi, http://yujinrobot.com/portfolio-item/irobi-q/

[20] D. McNaughton and J. Light, “The iPad and mobile technology revolution: Benefits and challenges for individuals who require augmentative and alternative communication,” *Augmentative and Alternative Communication*, vol. 29(2), pp. 107-116, 2013.