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Social Robots as Assistants for Autism Therapy in Iran: Research in Progress

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Abstract—**Autistic children are often impaired in initiating and responding to Joint Attention. In recent years, there has been an increase in the application of robots in diagnosis and treatment of autism. The purpose of the current research has been primarily to originate the proper therapeutic scenarios and to implement two interactive humanoid robots as therapy assistants in autism treatment in Iran. To this end, the humanoid robots were programmed and teleoperated via Microsoft Kinect Sensor and PhantomOmni Haptic Robot to elicit reactions consisting of imitation of humans by the humanoid robots and vice versa. In this paper, we elaborate on the therapeutic items that we have designed to improve joint attention and imitation in autistic children through using humanoid robots. Moreover, the fairly promising results of some interventions conducted in a pilot study on four autistic cases will be addressed and discussed. Our research target is to increase social interaction and involve autistic children in dyadic/triadic interactions which seems quite possible due to the findings of the pilot study conducted.**

***Keywords**:* Human-Robot interaction (HRI), Autism Spectrum Disorders, Humanoid Robots, Joint Attention, Imitation

I. Introduction

Statistics have shown an epidemic increase of Autistic Spectrum Disorders (ASD) worldwide since the 1960s, this trend is also true for Iran**.** Autism is considered a brain development disorder which causes a lack of correct information processing, partial or complete impairment in language learning, impaired verbal and non-verbal communication, and problems in interpreting social situations [1, 2]. Autistic disorders are characterized by three major behavioral disorders: impaired interaction, impaired social communication, and impaired imagination and social creativity [3].

There is no clear cut agreement on the prevalence of autism, and estimates vary from up to 100 out of a population of 10,000 [3]. The most recent statistics indicate that 1 out of every 88 children born in the United States is autistic [5]. It is expected that more than 30,000 Iranians younger than 19 years old suffer from autism disorders [3].

Autistic children share some common behavioral patterns which can generally be detected and modified. Individuals with autism often have some form of disorder in initiating and responding to joint attention [3].

In recent years, robots have been increasingly used in education [4] and autism diagnosis and treatment [5-12]. Different mobile robots, as well as humanoid and animal-like robots have been used in different medical centers and research laboratories around the world.

Research focusing on applying robots in autism treatment have pointed out that robots increase enthusiasm, focus, and attention; and cause novel social behaviors such as joint attention and automatic imitation. Research also indicates that autistic children work quite naturally with robotic technologies [2, 13].

When interacting with robots, people are mainly impressed by the robot's appearance [5]. A variety of robots with different appearances and functions are currently being used around the world as therapy assistants in autism treatment: Infanoid [6], a robot the size of a human infant able to move its hands and to open and close its mouth and fingers; Face [7], a very natural looking robot with silicon skin and high functions in showing facial expressions; Robota [8], a doll equipped with motors and sensors which is capable of moving its hands and feet and dancing; Muu [9], a robot with one big eye and a cartoon-like appearance; Bandit [10], a humanoid upper body on a wheel base; Pleo [11] and Keepon [12], animal-like robots, respectively, in the shape of a dinosaur and a bird. The above mentioned robots are being used to elicit such behaviors as imitation, joint attention, and eye contact. The humanoid robot NAO, which is the main instrument of the current study, has also been used in a number of studies with the general aim of autism diagnosis and treatment and the specific aim of helping autistic children with imitation, joint attention, interaction, communication, making eye contacts, showing emotions, and/or eye gaze attention [14-17].

The eminent feature of robots is their high level of repeatability and flexibility, as well as working without

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getting tired or making complaints. Due to the fact that robots do not humiliate or belittle people, autistic people are expected to face less anxiety in interacting with robots, be more willing to participate in the exercises, and make more effort to learn.

The objective of this research is to explore the clinical application of two interactive humanoid robots as medical assistants in real interventions (definitely not as a substitute for the human therapist!) in treating and educating children with autism in Iran [20, 21]. This paper is a report on developing the necessary tools to improve imitation and joint attention, two important social behaviors, in children with autism. The results of a pilot study utilizing these tools will also be addressed and discussed.

II. Research Methodology

The current study consists of the following two phases: the technical phase and the clinical interventions.

A. Technical Phase

Our first step was to identify the necessary capabilities needed for a robot to be used for autistic therapy. Therefore, the following two robots were chosen by CEDRA. According to the required capabilities and the desired therapy scenarios, two humanoid robots called NAO and Alice manufactured by Aldebaran-Robotics and Robokind, respectively, have been purchased. Additionally, the Alice Robot is capable of showing human facial expressions. The features of the two mentioned robots are as follows:

NAO Robot: The NAO-H21 is a kid-sized humanoid robot with a height of 57.3 cm, weighting 4.5 kg, with 21 degrees-of-freedom. To be used in an Iranian context, this robot has been renamed “Nima” (Fig.1).

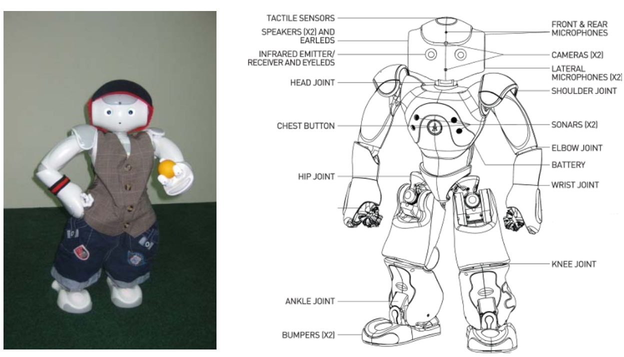

Fig. 1. A schematic overview of the NAO (Nima) Robot

Alice Robot: Alice, with the Iranian name “Mina” , 69 cm high, weighting 5.7 kg, with 32 degrees of freedom (21 degrees of freedom in her body and feet, and 11 degrees of freedom in her face), is capable of showing different facial expressions such as joy, sorrow, anger, fear, and so on, thus being of great interest for children. This robot can be programmed in C++ and Java (Fig.2). The robots’ capabilities such as body movements, speech, and facial expressions will be used to design different therapeutic scenarios. More details about this are presented in the next section.

Fig. 2. Alice (Mina) Robot

B. Clinical Interventions

The second phase of the study, the clinical interventions has been initiated with a pilot study on the autistic children at the “Center for Treatment of Autistic Disorders (CTAD)” in the presence of the robots and the human mediator.

The treatment process for a group of 3-10 year old patients will continue at least for a period of 10 weeks. The approach is a single subject design and the interventions are currently underway.

Robots are used in therapy sessions with different purposes; some of which are as follows:

- Quantitative and qualitative assessment of the amount of initiating and responding to joint attention by children with autism and investigating if any improvement is shown.
- Improving social and imitation skills in autistic children.
- Creating a happy, interesting, and exciting teaching atmosphere for autistic children.
- Educating the therapists to be able to apply a robot in different stages of the treatment.

As you can see in Figure 3, the set up of the pilot study consisted of the humanoid robot NAO, the Microsoft Kinect Sensor, and video projector to present and magnify the screen for our Kinect-Based recognition games. It is worth mentioning that each subject received the intervention before the other three subjects and their mothers. Accordingly, not only did each subject receive hints and applauds from NAO, but also from the mediator, the other three kids, and his mother.

Fig. 3. Set up for the pilot study

III. THERAPEUTIC SCENARIO DESIGN

In this section, the three main objectives of this paper will be discussed.

A. NAO and Alice Real Time Imitation by Microsoft Kinect

Imitation of the autistic patients' behavior is an effective way of triggering their attention toward the therapist [3, 8]. Imitation and turn-taking games are considered as good therapy to improve social interactions, sense of self, creativity, and leadership in children and even adults with autism.

We have used Microsoft Kinect sensor which gives us the real time position (x, y, z) of the player's joints. Using forward and inverse kinematics, we are able to teleoperate the robots and obtain good real time imitation of human.

To this end, eight joints of humanoid robots' upper body including HeadYaw and HeadPitch from the head, ShoulderPitch, ShoulderRoll, and ElbowPitch of both hands are commanded in order to have admissible real time position tracking of the users' hands and head.

The base frame, zero positions of the upper body joints of NAO, and the appropriate link frames are shown in Figure 4.

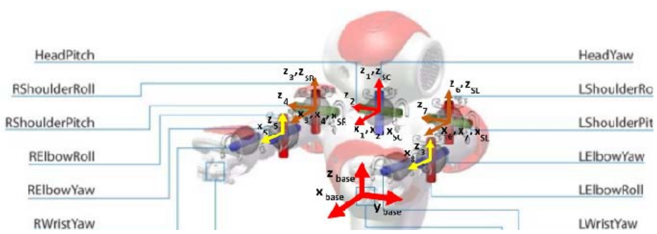

Fig. 4. NAO kinematic chains and upper body joints

The corresponding Denavit-Hartenberg (DH) parameters of NAO are given in Table 1.

TABLE I
DH Parameters for Head, Right Hand and Left Hand of NAO

	$\alpha_{i-1}\,(rad)$	a_{i-1}	θ_i	d_i
1	0	0	θ_1	0
2	$\frac{\pi}{2}$	0	$-\theta_2$	0
3	0	0	θ_4	0
4	α_{RS-RE}	$L_{RightArm}$	θ_5	0
5	0	0	θ_7	0
6	α_{LS-LE}	$L_{LeftArm}$	θ_8	0

where α_{RS-RE} is the angle between RightShoulder and RightElbow z directions. The homogenous transformation matrix ${}^{i-1}_{i}T$ is :

$$ {}^{i-1}_{i}T = \begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & a_{i-1} \\ \sin\theta_i.\cos\alpha_{i-1} & \cos\theta_i.\cos\alpha_{i-1} & -\sin\alpha_{i-1} & -\sin\alpha_{i-1}.d_i \\ \sin\theta_i.\sin\alpha_{i-1} & \cos\theta_i.\sin\alpha_{i-1} & \cos\alpha_{i-1} & \cos\alpha_{i-1}.d \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

We can combine DH transformation matrices of the corresponding joints to find the Head, Right Wrist, and Left Wrist positions of NAO:

$$ {}^{ShoulderCenter}_{Head}T = {}^{ShoulderCenter}_{1}T.{}^{1}_{2}T \quad (2)$$

$$ {}^{ShoulderRight}_{ElbowRight}T = Rot_y(\theta_3).{}^{ShoulderRight}_{3}T \quad (3)$$

$$ {}^{ShoulderRight}_{WristRight}T = {}^{ShoulderRight}_{ElbowRight}T.{}^{3}_{4}T \quad (4)$$

$$ {}^{ShoulderLeft}_{ElbowLeft}T = Rot_y(\theta_6).{}^{ShoulderLeft}_{5}T \quad (5)$$

$$ {}^{ShoulderLeft}_{WristLeft}T = {}^{ShoulderLeft}_{ElbowLeft}T.{}^{5}_{6}T \quad (6)$$

$$ {}^{ShoulderRightt}_{WristRight}P = {}^{ShoulderRightt}_{WristRight}T.[\mathrm{L}_{RightForehead},0,0,1]^T \quad (7)$$

$$ {}^{ShoulderLeft}_{WristLeft}P = {}^{ShoulderLeft}_{WristLeft}T.[\mathrm{L}_{LeftForehead},0,0,1]^T \quad (8)$$

The inverse kinematics for the considered eight joints are presented in Table 2.

TABLE 2
Inverse kinematics for the Head, Right Hand and Left Hand of NAO

HeadYaw	$\theta_1 = a\tan 2(\mathrm{H\_SC}_y, \mathrm{H\_SC}_x)$
HeadPitch	$\theta_2 = a\tan 2(\sqrt{\mathrm{H\_SC}_x{}^2 + \mathrm{H\_SC}_y{}^2}, \mathrm{H\_SC}_z)$
RightShoulderPitch	$\theta_3 = a\tan 2(-E\_SR_z, E\_SR_x)$
RightShoulderRoll	$\theta_4 = a\sin(\frac{E\_SR_y}{L_{RArm}})$
RightElbowPitch	$\theta_5 = a\cos(\frac{\vec{R}_{RArm}.\vec{R}_{RForehand}}{\lvert\vec{R}_{RArm}\rvert.\lvert\vec{R}_{RForehand}\rvert})$
LeftShoulderPitch	$\theta_6 = a\tan 2(-E\_SL_z, E\_SL_x)$
LeftShoulderRoll	$\theta_7 = a\sin(\frac{E\_SL_y}{L_{LArm}})$
LeftElbowPitch	$\theta_8 = -a\cos(\frac{\vec{R}_{LArm}.\vec{R}_{LForehand}}{\lvert\vec{R}_{LArm}\rvert.\lvert\vec{R}_{LForehand}\rvert})$

The same procedure could be done on Alice. Now, the robots are capable of imitating the patients through the data retrieved by the Microsoft Kinect sensor. Kinect's data sampling rate is 32 frames per second. The (x,y,z) coordinates of 20 points of the user's body are accessible in each data sampling. The accuracy of the imitation process is elaborated in detail in the Results section.

B. Teleoperating NAO and Alice by Haptic PhantomOmni

Operating a humanoid robot is not an easy task for patients and therapists. Empowering autistic children to move the robot joints arbitrarily can cause the children to show creative social behaviors. This novel therapeutic item designed in the current study, may also help them get involved in triadic Child-Robot-Therapist and Child-Robot-Child interactions.

To reach this goal, we have used a 6-DOFs haptic manipulator robot manufactured by The Sensable Technologies PHANTOM, as an interface between users and our humanoid robots. The degrees of freedom of Haptic

PhantomOmni are shown in Figure 5. The first three DOFs of this device are active while joints 4-6 are passive. The haptic manipulator makes it possible for users to touch or manipulate virtual objects, and it can apply force feedback on the user's hand.

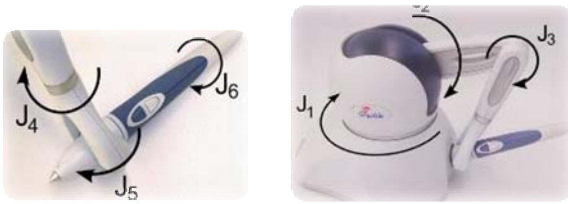

Fig. 5. Haptic PhantomOmni Robots and its 3 active and 3 passive DOFs

Autistic children or others can move the haptic device's pen in 3 dimensions of space and use it as a remote controller to enjoy playing with the humanoid robot.

The $\theta_1, \theta_2, \theta_3$ and θ_5 values recorded by PhantomOmni encoders are assigned to HeadYaw, HeadPitch, RightShoulderRoll, and RightElbowPitch joints of NAO and Alice, respectively. Similar to the previous subsection, the data have been sent via wireless to robots in order to have real time position tracking.

C. Therapeutic Games Design

Delayed development of joint attention, is one of the central disorders in individuals with autism [3]. Utilizing humanoid robots is expected to improve low- and high-level joint attention behaviors such as eye contact, showing, pointing, and gaze shifting through different therapies.

Up to the present time, the programming and automation of the robots to have behavioral-verbal interactions with the patients, as well as, their preparation to take part in different therapeutic situations have been completed and piloted. The robots have been programmed using the robots' speech, movement, and facial expressions capabilities, to implement a number of different therapeutic sessions to improve joint attention and imitation of autistic children.

To exemplify, they are capable of waving, saying hello and goodbye, one-leg balance in order for the autistic children to imitate the action, pointing to different pictures and asking the autistic child to do the same, expressing happiness for a gift or to encourage the children, or sadness during clinical interventions.

Moreover, they can provide verbal reinforcement based on the effectiveness of the responses given by the autistic child (especially in the Kinect-based games designed). They also teach different colors by changing the color of the LEDs in the robot's eyes and body while introducing the color, and playing music for children while dancing (Fig. 6).

Reinforcement and rewards are given for the performance of any of the joint attention skills. The rewards given consist of smiling, giving hugs and kind thanking words. Having the robot and the therapist imitate the child while the child is involved in a game is considered as an effective way to establish joint attention opportunities.

The therapeutic games designed to this date are as follows:

1. Fruit-animal recognition game which is a Kinect-based game,
2. NAO and Alice being operated by the patient via the PhantomOmni Haptic Robot,
3. NAO imitation of the patient (Kinect-based) and vice versa through a dyadic/triadic interaction,
4. NAO's pointing to specific directions to be tracked by the patients in order to improve their joint attention, and
5. NAO giving instructions and changing its eye color to be recognized by the patient

Fig. 6. NAO and Alice robots in autism treatment process (teaching colors, pointing to a picture, one-leg balance, waving, and smiling)

IV. Results and Discussion

In this section, the experimental results of teleoperating NAO using Microsoft Kinect sensor and the pilot study interventions will be addressed.

A. Robot Imitations

We have provided a C# code to save and process the joints' positions data gathered by Kinect. The goal is to have humanoid robots (NAO and Alice) imitate human upper body movements. Accordingly, the key points necessary for this purpose are Head, Center Shoulder, both Right and Left Shoulders, Elbows, and Wrists. Using inverse kinematics equations presented in Table. 2, the equivalent joint angles of NAO are calculated and sent wirelessly to the robot.

Fortunately, the sampling rate of Kinect is adequate for good imitation. The lowest acceptable value for fraction of maximum speed of robot actuators is limited by imitation time delays. The upper limit is restricted by jerk increase in robot actions. It was experimentally found that these two requirements were met when this fraction was set to 0.8.

Kinect data are noisy and the absolute position error of a fixed point may be more than 10 centimeters. Therefore, the data are filtered in order to smooth out short-term fluctuations through two methods: a) simple moving average of the previous 10 data, and b) 4^{th} order low-pass Butterworth filter with a cutoff frequency of 6 Hz.

As a case study, a person stood in 2 meters in front of the Kinect and moved his hands and head. The whole process took 113.4 seconds and included: movement of hands in arbitrary directions, elbows' flexion, drawing a circle and a square clockwise and counterclockwise, and left/right and up/down head movements.

Because of the difference in lengths of arms and forehands of the human and the robot, the data have been normalized in order to be comparable in evaluating tracking accuracy.

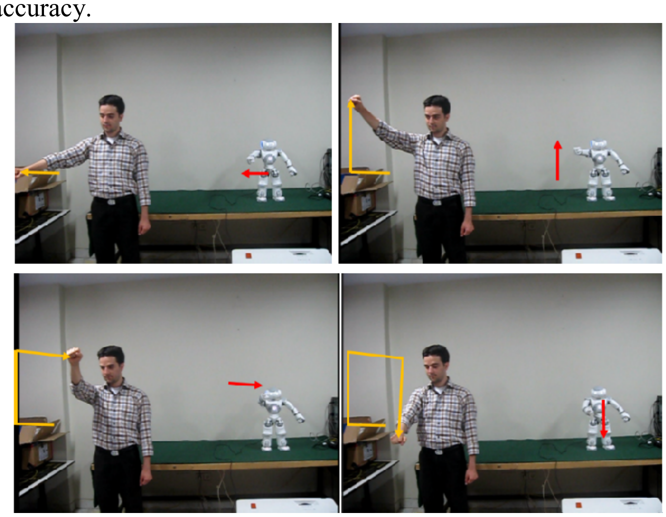

Fig. 7. Snapshots of drawing a square by the user

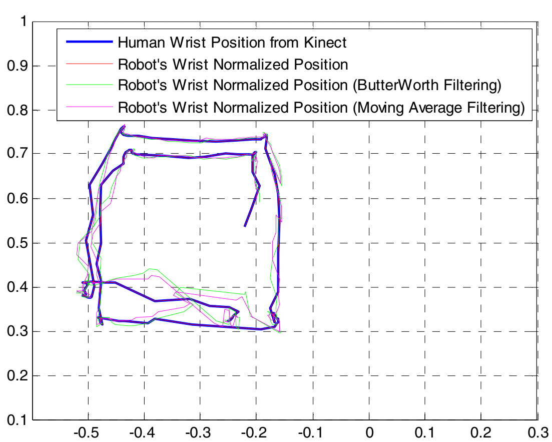

Fig. 8. Right wrist positions while drawing a square for four situations

In Fig.7, four snapshots of the process of drawing a square by the person are shown. Fig. 8 depicts NAO's right wrist position in three situations: unfiltered, applying moving average, and Butterworth filters to a person's right hand angle signals in a y-z plane. Fig.9 shows the right hand's angles versus time during the process of drawing a square. This part starts from t=30.9(s) and lasts to t=35.9(s).

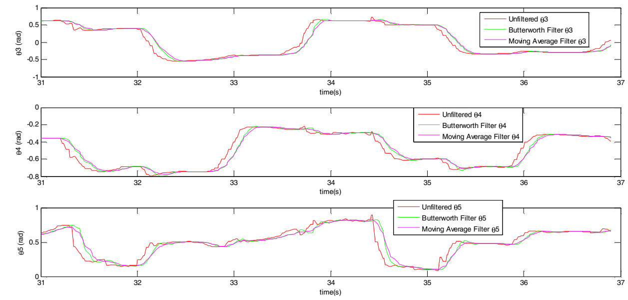

Fig. 9. Right hand's DOF's versus time during drawing a square in unfiltered and filtered situations

According to Figs.7-9, the NAO is able to imitate the person very well. The imitation accuracy is completely satisfactory for our future clinical intervention sessions and therapeutic design.

Although, usage of moving average or Butterworth filters decreases the imitation accuracy and slightly increase its time delay, filtering the angles' data makes the robot's movements much smoother and more reliable; and the robot's joints and body experience lower accelerations and less jerks. The robot's imitation delay time is less than 0.5 second in the unfiltered and filtered angles' data.

B. Interventions

In an attempt to conduct a pilot study focusing mostly on improving imitation and joint attention in autistic children through the games we had designed, a two-session intervention program was held.

As mentioned earlier, our sample consisted of 4 male subjects (S1, S2, S3, and S4) with the mean age of 8: S1, 9 years old, diagnosed with Asperger's syndrome; S2, 8 years old, diagnosed with mild Asperger syndrome as well as hyperactivity; S3, 7 years old, also diagnosed with mild Asperger's syndrome and hyperactivity; and S4, 7 years old, diagnosed with low-functioning autism.

Below is a report of each of our four subjects' performance at each intervention session.

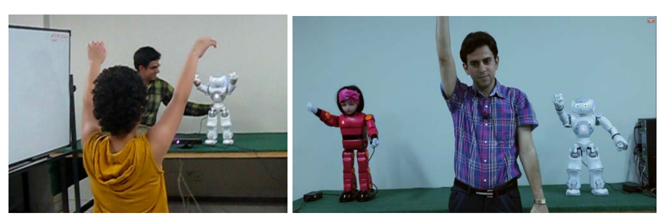

Fig. 10. (a) S1 imitating NAO (b) The human mediator giving instructions for imitation games

At the first session, S1 participated in the imitation game. He had to imitate NAO's hand movements, and one-leg balance which he managed to do successfully. He was found to enjoy this game, smiling, looking at the human mediator, and responding to his hints. At the second session, however, S1 was to make some hand movements and NAO would imitate him. This game also turned out to charm both S1 and other subjects observing his performance (Fig. 10).

S2 did the fruit-animal recognition game at the first session. He had to raise his right and left hand respectively to recognize animals and fruits, while NAO gave him hints and applauded him for correct answers. The mediations from the robot turned out to be pretty interesting to the subjects. They were laughing out loud enjoying the game. S2 could successfully complete this game with 12 correct answers out of 12. At the second session, S2 had the chance to control two humanoid robots, NAO and Alice, via the PhantomOmni Haptic Robot. This game also caused both the parents and the subjects to laugh out loud.

S3 also did the fruit-animal recognition game at session 1 and controlled the two robots at session 2 via the PhantomOmni Haptic Robot. During the former one, he was enjoying NAO's mediations and he also responded to his mother's hints. As a result, he completed the game with 10 correct answers out of 12. The joy and interaction with the human mediator was also true for him within the latter game (Fig. 11).

Fig. 11. S3 controlling NAO and Alice via the PhantomOmni Haptic Robot

Due to the fact that the target group of our imitation and joint attention games is mainly low-functioning autistic children, our main focus was on S4 who suffers from low-functioning autism. During the first session, unlike the other three subjects who were volunteers to participate in the games, he was not showing much interest in participating in the games. He was wandering around the room, distracted by such equipments as keyboards. He just wanted to push NAO's chest button and figure out what it was capable of doing. At the second session, however, we explicitly asked him to participate in some games. He had to stand in front of NAO and Kinect and act based on the instructions NAO was giving him orally. First, he had to recognize NAO's eye color that changed three times, and S4 recognized each of every 3 colors correctly. Then he had to imitate NAO's movements (Fig. 12-a). He was involved in a triadic interaction, responding to NAO's and human mediators' mediations (given by the operator and his mother), even though he seemed a bit confused at first. He had some extra movements like he expected NAO to imitate him, too. In the third item, NAO was pointing to different directions and S4 had to look at that specific point. Again he did not follow the instruction completely right, since he was still imitating NAO, pointing to the places NAO was pointing to (Fig. 12-b).

Fig. 12. (a) S4 imitating NAO (b) S4 involved in the joint attention game

V. Conclusion

In this paper, three main objectives were described. Teleoperating NAO using Microsoft Kinect was the first and the main goal of this article. Results showed that the imitation processes are completely acceptable based on good NAO movement quality and low imitation time delay. Similar to this but easier, NAO can also be teleoperated using a haptic robot as a remote controller. The same procedure has also been done on the Alice robot. Finally, it was shown that real time humanoid robot imitation of a person and vice versa is possible.

Despite the fact that no statistical or quantitative analysis is in hand for the time being, our qualitative analysis of the above-mentioned pilot study highly suggests that, in line with the findings of many other studies, autistic children seem to fully enjoy the presence of a robot and to be eager to participate in the therapeutic items involving a robot and to get involved in triadic interactions (robot-patient-human mediator interactions). Moreover, low-functioning autistic children seem to have more potentiality to improve through these games. Those suffering from mild Asperger's syndrome already showed good performance even in the first intervention.

Using the robots' speech, movement and facial expressions capabilities, we have designed different appropriate therapeutic scenarios to improve joint attention and imitation of autistic children. Clinical interventions are currently underway.

It is anticipated that the autistic children treated with this technology will enjoy faster improvement regarding making eye contact, initiating and responding to joint attention, imitation, and dyadic/triadic interactions. Moreover, a proper database associated with robotic assisted autistic treatment will be collected which may be used in comparing the effects of this new approach with more traditional methods. We expect this research to potentially provoke future study along this line.

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REFERENCES

[1] Edwards, W. (2011). “The autism physician handbook”, (A. Roozbeh, Trans.). Tehran: Qatre publication.

[2] Scassellati B., “Investigating Models of Social Development Using a Humanoid Robot”. In Proceedings of the International Joint Conference on Neural Networks, 2003.

[3] Pouretemad, H. (2011). “Diagnosis and treatment of joint attention in autistic children”, (in Persian), Tehran, Iran: Arjmand Book.

[4] Meghdari A., Alemi M., Ghazisaedy M., Taheri A.R., Karimian A., Zandvakili M., 2013, “Applying Robots as Teaching Assistant in EFL Classes at Iranian Middle-Schools”, EMET 2013, Venice, Italy.

[5] Scassellati B., Admoni H., Matari´c M., 2012, “Robots for Use in Autism Research”, Annual Review of Biomedical Engineering 2012, 14, pp. 275-294.

[6] Kozima H, Yano H. 2001. “A Robot that Learns to Communicate with Human Caregivers”. Proc. First Int. Workshop Epigenet. Robot. Sept. 17–18, Lund, Swed.

[7] Pioggia G, Sica ML, Ferro M, Igliozzi R, Muratori F, 2007. “Human-Robot Interaction in Autism: FACE, an Android-based Social Therapy”. Proc. 16th IEEE Int. Symp. Robot Hum. Interact. Commun.

[8] Billard A. 2003. “Robota: Clever Toy and Educational Tool”. Robot. Auton. Syst. 42, pp. 259–69

[9] Kozima H, Nakagawa C, Yasuda Y. 2007. ”Children-Robot Interaction: a Pilot Study in Autism Therapy”. Prog. Brain Res. 164, pp. 385–400.

[10] Ferrari E, Robins B, Dautenhahn K. 2009. “Therapeutic and Educational Objectives in Robo-Assisted Play for children with autism”. Proc. 18th IEEE Int. Symp. Robot Hum. Interact. Commun. (RO-MAN 2009), Sept. 27–Oct. 2, Toyama, Jpn., pp. 108–114.

[11] Kim E, Paul R, Shic F, Scassellati B. 2012. “Bridging the Research Gap: Making HRI Useful to Individuals with Autism”, J. Hum.-Robot Interact. 1

[12] Stanton CM, Kahn PH Jr, Severson RL, Ruckert JH, Gill BT. 2008. “Robotic Animals Might Aid in the Social Development of Children with Autism”. Proc. 3rd ACM/IEEE Int. Conf. Hum.-Robot Interact. (HRI ’08), March 12–15, Amsterdam, pp. 271–78. New York: ACM

[13] Diehl JJ, Schmitt LM, Villano M, Crowell CR. 2012. “The Clinical Use of Robots for Individuals with Autism, Spectrum Disorders: a Critical Review.” Res. Autism Spectrum Disorders, 6, pp. 249–262

[14] Anzalone, S. M., Tilmont, E., Boucenna, S., Xavier, J., Jouen, A. L., Bodeau, N. & Cohen, D., 2014. “How children with autism spectrum disorder behave and explore the 4-dimensional (spatial 3D+ time) environment during a joint attention induction task with a robot”, Research in Autism Spectrum Disorders, 8 (7), 814-826.

[15] Barakova, E. I., Kim, M. G., & Lourens, T., 2014. “Development of a Robot-Based Environment for Training Children with Autism”, Universal Access in Human-Computer Interaction. Aging and Assistive Environments, pp.601-612. Springer International Publishing.

[16] Diehl, J. J., Crowell, C. R., Villano, M., Wier, K., Tang, K., & Riek, L. D., 2014. “Clinical Applications of Robots in Autism Spectrum Disorder Diagnosis and Treatment”, Comprehensive Guide to Autism (pp. 411-422). Springer New York.

[17] Feng, H., Gutierrez, A., Zhang, J., & Mahoor, M. H. 2013, “Can NAO Robot Improve Eye-Gaze Attention of Children with High