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Social engagement of children with autism spectrum disorder in interaction with a parrot-inspired therapeutic robot

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Abstract

This paper presents a series of results from a pilot study with ten participants to evaluate if children with autism spectrum disorder exhibit more social interaction interests when engaging with the parrot-inspired therapeutic robot, KiliRo, compared to with another human. Three sessions, each with different activities such as talking and singing that either the robot and a human encouraged the children to engage in, were conducted to monitor 12 types of social engagement behaviours in participants to compare the effects of engagement with a human and a parrot robot. The behaviours were recorded and analyzed using real-time video data of the interactions. The results indicate a positive influence of introducing the parrot robot to children on their social interaction. Also, the analyses revealed a significant difference in each of the session conducted based on the assessed 12 attributes, providing some indications for the potential benefits of human-robot interaction in therapeutic settings for children with autism spectrum disorder.

Keywords: autism spectrum disorder; social interaction, human-robot interaction; parrot-inspired robot; therapeutic robot

1. Introduction

The term 'autism' was first used by the psychiatrist Eugen Bleuler in 1911 to describe an individual's withdrawal from social life [1]. Since then, several terms were proposed to define Autism Spectrum Disorder (ASD), such as biological changes in the brain development, neurodevelopmental disorder, neurobehavioral condition, and behavioral disorder [2]-[5]. According to the latest Diagnostic and Statistical Manual of Mental Disorders (DSM), DSM-5, people

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with ASD exhibit persistent deficits in social communication and social interaction, and restricted and repetitive behaviour patterns [6].

Centers for Disease Control and Prevention (CDC) released data on the prevalence of autism in the United States for the year 2010, reporting that an estimated 1 in 68 (14.7 per 1000) school-aged children have been diagnosed with ASD. The report also mentioned that ASD is more common among male children than female children: 1 in 42 males versus 1 in 189 females [7]. CDC has further indicated that about 1 percent of the world population has some form of ASD [8]. This leads to the conclusion that there are about 74 million people with ASD around the world at the time of writing this report. In New Zealand, it is estimated that there are about 65,000 people living with ASD, which counts to 1.4% of the total population [9].

Educating and establishing interaction among children with ASD is very challenging due to the nature of the disorder. According to a study by the researchers at Harvard University, healthcare and education cost for an individual with autism average more than USD 17000 per year per child in the United States [10].

Previous studies involving children with ASD show positive influence of introducing mechanical devices, tablets, and robots in improving their quality of life. Particularly, engagement with robots has been proposed through several studies for facilitating social interaction of children with ASD among peers [11]-[14]. Involvement of robots in therapeutic setting for children with ASD is an active and emerging area of assistive robotics where bio-inspired robots have shown great potential [15]-[19]. Studies involving bio-inspired robots have reported improvements in psychological, physiological, and social interaction abilities of children with ASD and also encourage studies in the field of robotics [20]-[23].

Involvement of bio-inspired robots as agents for therapeutic interaction has been explored in several studies. They have indicated the benefits of bio-inspired therapeutic robots and their abilities to not only to mimic the behaviour of their biological counterparts but also to retain the essence of benefits provide to humans. Nao, for example, is a human-like robot developed by the French company Aldebaran Robotics. Initially, this robot was used extensively in soccer playing robot competitions, now being explored in therapeutic settings involving children ASD. Adriana et al. [11] presented a series of four single-subject design experiments to investigate if children with ASD show increased social engagement while interacting with the Nao robot, compared to a human partner in a motor imitation task. The study reported various findings such as the participants' attention toward the robot when its eye colour was changed or physical movement was performed. The authors indicated that human-robot interaction in motor-imitation tasks may be beneficial for a subgroup of children with less eye contact. Luthffi et al. reported the initial response of children with ASD engaging with Nao robot during the robot-assisted therapy (RAT) [15]. The authors evaluated the stereotyped behaviour in children with ASD during the RAT and a regular classroom session using Gilliam Autism Rating Scale-2nd edition (GARS-2) and reported that participants exhibited less stereotyped behaviour during the RAT compared during usual human-human classroom sessions.

Another human-like robot, Zeno, was developed by Hanson robotics and released in 2012 with the aim to provide a more realistic robot than other facially expressive robots. This robot has been explored as a teacher and intervention tool to improve social behaviour of children with ASD. A study reported by Nahum et al. [16] investigated the effects of Zeno robot in autism therapy to improve physiological movements such as arm and torso motions of children with ASD in a therapeutic setting. The authors hypothesised that enabling the robot to make arm and torso movements during therapy would encourage children to mimic the motion and enhance their motor skills and improve their social interaction abilities.

Kinesics And Synchronization in Personal Assistant Robotics (KASPAR) is a child-sized humanoid robot, developed with minimal expressive features specifically for human-robot interaction studies. KASPAR robot has been used in many human-robot interaction studies including studies involving children with ASD. Joshua et al. used KASPAR in a triadic, collaborative game involving the robot and two children identified with ASD [17]. Six children with ASD played 23 controlled play sessions each, both with and without the robot. The study reported that detailed observational analyses on children's behaviour showed improvement after they played as pairs with the robot.

In assistive robotics, robotic platforms inspired by several animals have been designed and developed to provide the therapeutic benefits that linked to animal assisted therapy while minimising its negative effects, such as allergies and biting. Artificial intelligence robot (AIBO) is a dog-like robotic pet designed and developed by Sony. Cady et al. [12] investigated the effects of AIBO robot in improving social engagement over a simple mechanical toy with no ability to detect or respond to its physical or social environment. Eleven children diagnosed with ASD, aged between

5 and 8 years were involved in the study. The study indicated that children spoke and interacted more with the AIBO robot in comparison to the simple mechanical toy. The study also reported that participants engaged in fewer symptoms of ASD while interacting with AIBO robot.

CuDDler, a polar bear like companion robot was designed to be an assistive and educational tool for children with ASD. This robot has been used in therapeutic settings involving children with ASD to provide psychological and physiological benefits. Wong and Zhong [13] examined the effects of a small and portable robotic platform in improving learning and social communication skills among children with ASD using the CuDDler robot. The authors involved eight children between the ages of four and six years diagnosed with ASD. It is reported that 90% of the participants responded positively in learning and communication abilities after interaction with the robot. It is also reported that there were significant improvements in turn-taking skills and longer duration of eye-contact engagement among participating children.

Lack of emotion expression is often considered as issue needing therapeutic interventions in children with ASD. Helping children recognise different emotions could also help in increasing interest in interacting with others. Cristina et al. used Probo, an imaginary animal-like robot with a trunk, animated ears, eyes, eyebrows, eyelids, mouth, neck, and an interactive belly screen with a huggable appearance to identify whether children with ASD increase their capabilities in identifying situation-based emotion of the robot after interaction [18]. The authors studied the effects of Probo robot in making the participants recognise sad, happy, and neutral emotions. The results indicated that participating children showed improved performance in identifying emotions with an overall recognition rate of 84%. The authors concluded that the Probo robot can help in teaching emotions to children with ASD.

Based on the reported benefits of bio-inspired therapeutic robots in human-robot interaction studies, we have designed and developed a parrot-like robot to improve learning and social interaction abilities of children with ASD [20] & [22]. Parrots have been used in several therapeutic settings and have reported to provide psychological and social interaction benefits. Pepperberg, an animal psychologist who has been studying parrots for more than 30 years, has reported a variety of intelligent behaviours in parrots in more than 100 publications. She reported that the parrots can speak and use words in a meaningful manner [24]. An African grey parrot, Alex, from her laboratory had a vocabulary of more than 100 words and could count numbers up to ten [25]. Alex was also able to engage effectively in two-way conversations and differentiate materials such as wood and paper.

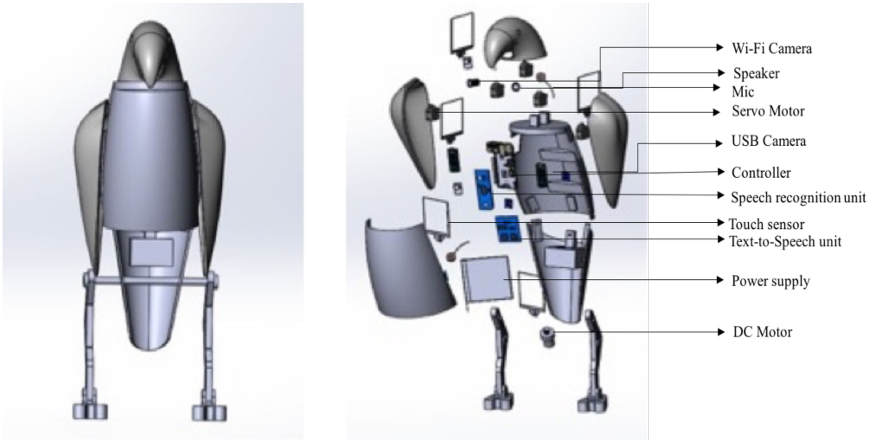
Parrots have previously been involved in therapeutic settings for patients with post-traumatic stress disorder, bipolar disorder, and psychotic tendencies [26]-[28]. Haw presented the benefits deploying parrots as therapeutic animal for psychiatric patients [29]. In this work, parrot is recommended for the house bound, the lonely, and patients with depression. It is also reported that parrots can be very helpful for middle-aged women suffering from the empty-nest syndrome. Interestingly, the author reported that parrots can provide better companionship to owners than television by interacting and communicating effectively.

Parrots have been used in elderly care in Japan, with numerous reports of benefits to participants, such as improvement in sight, sound, and smell sensitivity [30]. In the U.K., children with ASD reported calming behaviour after interacting with a Caique parrots [31]. In another study, an African grey parrot named Sadie reported to help his owner who had bipolar disorder with psychotic tendencies [32]. The parrot helped his owner by repeatedly saying ‘calm down’ when the owner was in a stressful situation. This study claims that the parrot could recognise the emotional state of the owner.

With such promising benefits of parrots to humans in therapeutic settings, there still prevails the same set of constraints as with any other animal-assisted therapy. One common risky behaviour reported by parrot owners is biting [33]. Having large beaks, parrots can cause injury to humans. Diseases spread by parrots, such as parrot fever spread through Chlamydia psittaci bacteria, can also be a threat in parrot-assisted therapy [34]. These challenges provide the possibility for the design and development of a parrot-inspired therapeutic robot, which can be explored in improving social interaction abilities of children with ASD.

2. KiliRo robot

KiliRo is a parrot-like therapeutic robot designed to improve learning and social interaction abilities of children with ASD. The name KiliRo is the combination of two words: Kili and Robot, where Kili is the Tamil word denoting parrot. The robot has three parts. The upper part consists of one head with two eyes and a beak. It contains one power button, one touch sensor, two wireless cameras, two servomotors, a microphone, and a speaker. The middle part consists of a body with two wings and accommodates the controllers, speech synthesis module, text-to- speech module, USB camera, power supply, six touch sensors, one ultrasonic sensor, three servo motors, one DC motor, and a worm-gear unit. The lower part has two legs with feet, and walking is made possible through a biped mechanism. The robot has the dimension of 240mm x 110mm x 90mm (height x width x depth) and weighs approximately 2000g. The KiliRo robot's CAD design, exploded view and the physical architecture is presented in Fig. 1 (a) and (b) and 2 respectively.



(a) (b)

Fig. 1. (a) KiliRo – CAD model; (b) KiliRo – Exploded view.

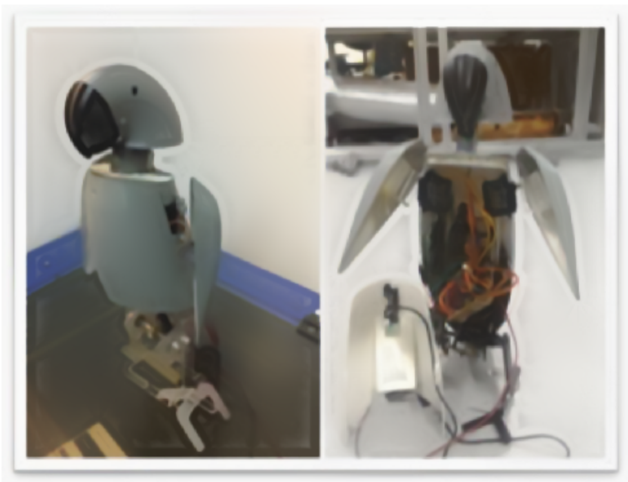


Fig.2 KiliRo robot – Physical architecture

3. Method

3.1. Participants

Ten children diagnosed with symptoms of ASD, seven boys and three girls, ranging in age from 7 to 11 years (mean = 8.70, standard deviation = 1.16), were recruited from a special school for children with ASD in Chennai, India. The participants' autism behaviour were diagnosed and confirmed by a pediatrician and a child psychologist both having a minimum of five years of experience in practice. We have also used the Childhood Autism Spectrum Test (CAST) questionnaire aimed at parents for evaluating autism behavior in children. The questionnaire used contains 39 yes-or-no questions to parents and scores of above 15 are interpreted as their children having symptoms of ASD. All children participated in the study scored a minimum of 17 points in CAST questionnaire. Out of 17 participants initially screened, seven children were excluded from the study due to various reasons including, CAST score below 15, and severe autism behaviour as identified by the pediatrician and child psychologist.

3.2. Study setup

The study was conducted in a 6m x 6m room at the special school. An adjacent room with 4m x 4m dimension was used to monitor the participants' behaviors during the sessions through three cameras installed in the study room. A speaker was placed in the room to use during the second and third sessions. Ten research assistants were recruited and allocated one child each to monitor 12 behaviors during each session. The robot was placed in a table with 1m x 1m dimension at the center of the study room during the child-robot interaction sessions. During the child-person interaction sessions, the person used the same 1m x 1m space of the room.

3.3. Procedure

The This pilot study was conducted over a period of three days with nine sessions, each one lasting for a minimum of 15 minutes and separated by a 15-minutes break in between sessions. Pre-test and post-test design with two interventions based on the ABC design [] across ten participants was used to compare the effects of improvements in interaction among children with ASD. In our study, three sets of outcome measures were collected: one at baseline without human and robot interaction, another one during human interaction, where a new person was introduced to participants, and the third, with robot interaction. In baseline identification, all ten participants were gathered in the study room and data were collected for 12 behaviors as defined below:

- ➢ Looking at the person / robot refers to the participant looking at the person / robot for a minimum of ten times during the 15-minute session.
- ➢ Going close to the person / robot refers to the participant moving toward the person / robot at least two times during the 15-minute session.
- ➢ Touching the person / robot refers to the participant touching the person / robot at least once during the 15-minute session.
- ➢ Smiling / laughing at the person / robot refers to the participant looking the person / robot and smile / laugh at least three times during the 15-minute session.
- ➢ Hitting the person / robot refers to the participant hitting the person / robot in a friendly manner at least once during the 15-minute session.
- ➢ Having verbal / non-verbal communication with the person / robot refers to the participant talking or showing gesture signal to the person / robot at least three times during the 15-minute session.
- ➢ Looking at other participants refers to the participant looking at least three of the other participants during the 15-minute session toward monitoring their attitude or response.
- ➢ Going close to other participants refers to the participants moving toward other participants at least two times during the 15-minute session.

- Touching other participants refers to the participant touching other participants at least once during the 15-minute session.
- Smiling / laughing during the session refers to the participants smiling / laughing in response to the action performed by the person / robot at least three times during the 15-minute session.
- Hitting other participants refers to the participant hitting other participants in friendly manner at least once during the 15-minute session.
- Having verbal / non-verbal communication with other participants refers to the participant talking or showing gesture signal to other participants in response to the actions performed by the person / robot at least three times during the 15-minute duration.

'Yes' was recorded when the frequency requirement for each behavior had been met. The criteria for each behavior was set as recommended by a child psychologist.

3.4. Study sessions

During the first session, the person / robot was simply present at the centre of the study room and to identify the behaviours of children when a new person/robot was introduced in their environment. The session continued for 15 minutes. During the second session, the person / robot pronounced letters of the English alphabet and numbers through a recorded voice. In the third session, two songs were played in the regional language. During the session with person, he performed few dance movements and acted to sing the song. In session with the robot, its wings and head were moved when the songs were played

4. Results

Over all sessions with ten participants, we recorded a total of 307 minutes of interaction with the robot and human. The participants had 147 minutes of human-human interaction (phase B) and 145 minutes of human-robot interaction (phase C). During phase A (15 minutes), the participants interacted with their teacher. During each session, the number of unsuccessful attempts to initiate interactions were recorded for each of the above mentioned twelve behaviors to evaluate the difference in interaction between person and robot sessions. It is noted that most of participants exhibited more interactions during the robot sessions compared to person sessions. The responses for 12 behaviours according to the terms defined above are presented in Table 1 below.

Table 1 Participants' responses to 12 behaviours

	1	2	3	4	5	6	7	8	9	10	11	12
Baseline (A)	2	3	6	4	7	3	7	7	7	8	10	7
Person session (B)												
Session I	7	8	10	10	10	8	8	10	10	10	10	10
Session II	5	8	10	8	8	6	9	10	10	9	10	10
Session III	4	8	10	7	7	9	10	10	10	10	10	10
Robot Session (C)												
Session I	3	6	6	8	6	7	7	9	9	8	9	9
Session II	3	4	6	6	5	5	7	9	9	8	9	9
Session III	1	4	4	4	4	1	6	9	9	8	9	9

Mean, standard deviation (SD), and confidence interval (CI) with 95 % margin for the sessions with person and robot interactions is presented in Table 2 and interval plot diagram for three sessions with person and robot is presented in Fig. 3.

Table 2 Mean, SD, and CI for the sessions with person and robot interactions

Factor	Mean	SD	CI (95%)
Person Session I	9.25	1.14	(8.07, 10.43)
Person Session II	8.58	1.68	(7.40, 9.76)
Person Session III	18.75	1.91	(7.57, 9.93)
Person Session I	7.25	1.81	(6.07, 8.43)
Person Session II	6.67	2.15	(5.49, 7.84)
Person Session III	5.57	3.08	(4.49, 6.84)

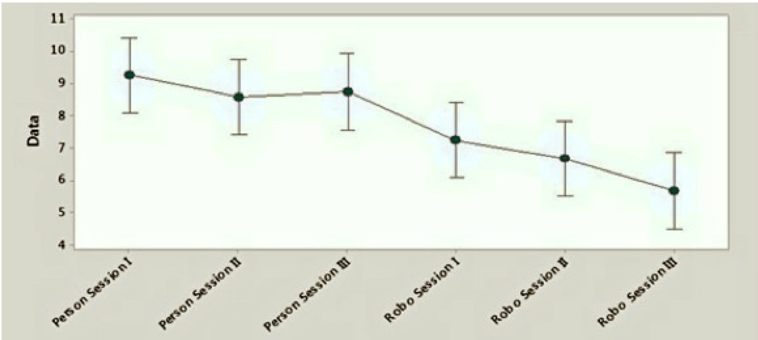


Fig.3 Interval plot diagram for three sessions with person and robot

The mean value of unsuccessful attempt to exhibit behaviour to initiate interaction, denoted by 'No' for the twelve behaviors decreased with successive sessions and reaches its lowest value in the sixth session. This indicates that children with ASD exhibited more interaction when the robot was introduced compared to the sessions with person. It is also noted that he interaction among children was more during the last session in which the robot was singing song. The results were tested using paired-samples t-tests to compare the effects of introducing a person and a robot among children with ASD. Paired-samples t-tests for three session's pair response with person and robot is presented in Table 3.

Table 3 Paired-samples t-tests for three sessions

Factor	Pair test	Mean	t	df	Sig (2 tail)
Pair 1	Person session1 – Robot session1	2.00	5.42	11	.00
Pair 2	Person session2 – Robot session2	1.92	5.70	11	.00
Pair 3	Person session3 – Robot session3	3.08	4.87	11	.00

Through paired-samples t-tests, it is identified that there is significant difference between introducing a new person and KiliRo robot among children with ASD. Through this user study, it is identified that introducing KiliRo to children with ASD has more effect in social interaction than introducing a person.

5. Conclusions

Improving social interaction among children with ASD is one of the challenging task and several researches have explored new methods to this end. Involving robots in therapeutic settings for children with ASD has indicated success in increasing interaction interests in children with ASD. In this research study, we deployed the parrot robot, KiliRo to help improve social interaction abilities of these children. The study indicated significant improvements in children's interaction abilities as opposed to sessions with human involvement. The 12 types of social engagement behaviors monitored during the study reported that KiliRo robot has the potential to act as a social robot to improve social interaction in children with ASD.

Nevertheless, this study has several limitations. Particularly, the sample size was relatively small and thus limits generalization. Secondly, the study was not conducted long-term, with no follow up. While the behavior from Person Sessions I to III appeared to have stabilised, the behaviour of Robo Sessions I to III were exhibited a trend. Future work may apply separate stability criteria for separate individuals to ensure the behaviour of each of the participants was stable before continuing with the next phase. In our future studies, we aim to address these limitations by conducting study with large group of participants to further study the effects of KiliRo robot in improving social interaction abilities of children with ASD. Another possibility of future work is to conduct the user study with longer duration over several months. The third area of further study is to conduct the cross-country studies to validate the robot in different geographical locations.

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Ethics

Approval for this research was granted by the Auckland University of Technology Ethics Committee (AUTEC) on 11 March 2016. Ethics Approval Number: 15/397.

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