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Investigating the Effects of Robot-Assisted Therapy among Children with Autism Spectrum Disorder using Bio-markers

Jaishankar Bharatharaj[1], Loulin Huang[1], Ahmed Al-Jumaily[1] , Mohan Rajesh Elara[2] and Chris Krägeloh[1]

[1]Institute of Biomedical Technologies, Auckland University of Technology, Auckland, New Zealand
[2]Engineering Product Development, Singapore University of Technology and Design, Singapore

E-mail: jaishankar.bharatharaj@aut.ac.nz

Abstract. Therapeutic pet robots designed to help humans with various medical conditions could play a vital role in physiological, psychological and social-interaction interventions for children with autism spectrum disorder (ASD). In this paper, we report our findings from a robot-assisted therapeutic study conducted over seven weeks to investigate the changes in stress levels of children with ASD. For this study, we used the parrot-inspired therapeutic robot, KiliRo, we developed and investigated urinary and salivary samples of participating children to report changes in stress levels before and after interacting with the robot. This is a pioneering human-robot interaction study to investigate the effects of robot-assisted therapy using salivary samples. The results show that the bio-inspired robot-assisted therapy can significantly help reduce the stress levels of children with ASD.

1. Introduction

The rapid increase in the number of children with autism around the world is becoming noticeable worldwide, putting a serious pressure on the human society to develop modern technological solutions to improve the lives of these individuals with autism. Centres for Disease Control and Prevention in the United States estimated that in 2014 about 1 percent of the world population (or about 74 million people) have some form of autism spectrum disorder [1]. Given that the medication to cure autism is yet to be found, many researchers are exploring new ways to help improve the lifestyle of these children. Robot therapy for improving the psychological, physiological, and social interaction abilities of children with autism is finding new directions in recent years. Particularly, biologically inspired robots were able to help increase the interaction interest and learning ability of children with autism. For instance, dog-like AIBO robot proved to be successful in establishing social interaction in children with autism [2]. In that study, the authors introduced a dog-like robot to eleven children and reported that the participants were much interactive with the robot than with a non-interactive dog-like toy. Paro, a seal-like robot has also reported success in improving social interaction abilities through various studies [3]-[5]. Probo is an imaginary animal-like robot used in autism therapy to improve social interaction and reduce stress [6]. Nao is a human-like intelligent robot initially used extensively in soccer playing robot competitions. In recent years, researchers have also used Nao robot in autism therapy giving various benefits such as improving learning, social interaction and joint exercise [7]-[8]. Animal-like robots have been developed by highlighting the benefits of their living counterparts in

animal assisted therapies. The need for developing bio-inspired robots have been centred on the risk and challenges of using real animals. For instance, dogs were used extensively in animal-assisted therapy (AAT) with numerous reported benefits [9]-[10]. Likewise, there are many species that can provide therapeutic benefits to human being [11]-[13]. Nevertheless, hospitals and doctors show limited interest due to the fear of biting, allergy, and safety and ethical issues of using animals [14]-[16]. One such potential creature that can provide therapeutic benefits is parrot. After dogs, cats, and fish, parrots are thought to be the most common household pet [5]. Parrots are good in mimicking the human voice and other sounds. These birds are naturally able to speak and engage in two-way conversations with humans [17]. Pepperberg, an animal psychologist from the Harvard University has reported the intelligence of parrots through many studies. Particularly, her reports on Alex, the African grey parrot indicated that the parrots are not only able to speak but are able to build a two-way conversation. Pepperberg reported that Alex was able to identify 50 different objects and understand the concept of smaller, bigger, same, and different [18]. Parrots have been used in therapeutic settings and have provided remarkable benefits to the human society. For instance, parrots have been used in therapeutic setting to help people with mental or physical disorder. African grey parrot named Sadie was able to help his owner who had bipolar disorder with psychotic tendencies. Sadie helped his owner by repeatedly saying 'calm down' when needed [5]. In another setting, the parrot was used to assist patients with post-traumatic stress disorder among war veterans in the United States [19]. It is also reported that the parrots are helpful in therapeutic settings with psychiatric patients [20]. The distinct feature of talking ability in parrots is very relevant and helpful in improving learning and social interaction abilities of children with autism. Parrots have been used in many therapeutic settings including elderly care and autism therapy earlier. For instance, in Japan, an elderly care centre implemented parrot therapy and reported improvements in senses, such as sight, sound, and smell [21]. In the UK, an autistic child reported calming behaviour after interacting with a Caique parrot that was used as an emotional support animal [22]. Nonetheless, using parrots with children with autism is still a risky choice due to biting, allergy, and parrot-spread diseases. Specifically, parrot fever is spread by birds through the bacteria called, chlamydia psittaci [23].

To overcome these traditional challenges in parrot-assisted therapies, we have developed an artificial parrot robot, KiliRo that mimics its natural counterpart in therapeutic setting retaining the merits while overcoming the shortfalls. In this paper, we present evidence that the parrot-inspired robot that we developed can help reduce stress levels of children with ASD. To report reduction in stress levels, participants' urinary and salivary samples were analysed for protein and alpha amylase levels respectively. Investigating sociopsychological changes using non-invasive methods are gaining more attention in therapeutic settings during the recent decades. Especially, the studies investigating the effects of new therapies and methods are widely using biological samples to report changes in various aspects, such as psychological, physiological, and social interaction. Investigating substances such as protein and alpha-amylase can provide in-depth knowledge about the biological changes in participants during the experiments. Even though other sampling methods, such as blood test can provide the values of these substances, using non-invasive method is preferred to avoid pain and need for experts to collect samples. Urinary samples and salivary samples are found to be more appropriate and convenient methods to investigate protein and alpha amylase levels respectively. For such reasons, we used urinary and salivary samples of children to report changes in their stress levels. The results show that the participants' stress levels has decreased significantly after interacting with the robot.

2. Study setup

2.1. Participants
Open invitation was sent to all potential participants in identified schools through convenient sampling method three weeks before the study. Parents were given two weeks to respond to the invitation. A total of 19 invitations were sent to which 14 parents' responded that they would be willing for their children to be involved in this experiments. A meeting was conducted with interested parents 7 days

prior to the experiments and a request was made to complete the Childhood Asperger Syndrome Test (CAST) questionnaire to identify the autism behaviour in their children. CAST involves a set of thirty-nine 'yes' or 'no' questions captured in a questionnaire to evaluate autism behaviour in children [5]. Children scoring 15 and above were classified to have symptoms of autism. Out of 17 children five were excluded from the study due to low score in CAST questionnaire and another two were excluded due to severe autism behaviour as judged by the paediatrician and the child psychologist. Finally, our experiments were conducted with seven participants over a duration of 49 days. Participating children were between the age group of 6 to 16 years and had no exposure to robots. The mean age of participating children was 10.0 years with a standard deviation of 3.51. To protect the identity of participants, their urinary and salivary samples were labelled as Subject1 through 7.

2.2. Study setup
Participating children were exposed to the robot for a minimum duration of 60 minutes each day over 49 days. Participants were allowed to interact and carry the robot freely. This study was performed with no compulsory attendance requirements for the participants. Nevertheless, the researcher and volunteers were present every day throughout the study adhering to the maximum working hours as instructed by employment rights in New Zealand and India. Four sessions were conducted each day with a minimum of 15 minutes per session. During the first session, the robot was placed on a table with the dimension of 3x3 square feet. The participants were allowed to have open interaction with the KiliRo robot. The second and third sessions involved activities around learning abilities of the robot. Letters of the alphabet and numbers were shown to the robot, and its ability to recognize them was demonstrated in front of participating children. During the fourth session, the robot was operated to move forward and backward while talking to the participants about its capabilities.

2.3. Urinary and salivary test
Literature points to non-invasive methods for assessing human psychological and social behavioural processes as a highly convenient and effective approach in many clinical settings. Particularly, these methods are found to be very useful in research studies involving special needs children. For instance, Wada and Shibata investigated the 17-KS-S and 17-OHCS hormone levels in elderly using urinary samples to evaluate the stress level in elderly while interacting with a seal-like robot [24]. In this study 12 participants aged between 67 and 89 years. The participants were assessed by mini mental state examination (MMSE) to investigate their mental cognitive state. During the study, the participants were allowed to interact with the PARO robot freely and the reactions of the participants' vital organ were investigated using urinary samples. The study reported in the 17-KS-S/17-OHCS ratio after two weeks of interaction with the robot.

However, there are other hormones in the human body whose proportional relationships to psychological changes are better quantified. It is identified that higher protein levels in urinary sample of higher stress levels in subjects [25]. Previous studies have reported that a person's alpha-amylase level generally increases during stressful situations [26]. Sympathoadrenal medullary (SAM) activity is examined in alpha-amylase test and increased alpha-amylase levels serves as an indicator of increased stress levels [27].

For our experiments presented in this paper, we used urinary and salivary tests to evaluate the biological changes in children with autism before and after interacting with our parrot-inspired robot, KiliRo. This is a pioneering human robot interaction studies to use salivary test for validating the effects of robotic engagement with autistic children. Urinary sample was used to measure protein levels in participating children and salivary sample was used to measure the alpha-amylase levels. Urinary and salivary samples of participating children were collected by their parents and was handed over to the laboratory technician on the first day of the study, before introducing our KiliRo robot. The first samples were collected on the first day of the study before the participants have interacted with the robot, while the second samples were collected during the last week of the study to evaluate the

changes in stress levels after interacting with KiliRo robot for over 7 weeks. Both the urinary and salivary samples were at the study venue between 9 a.m. and 11 a.m.

3. KiliRo

The schematic diagram of our KiliRo robot is illustrated in Fig. 1. The body frame of our robot was completely fabricated using a 3D printer. PLA (Polylactic Acid) and TPU (Thermoplastic Polyurethane) materials were used in printing the robot. The robot consists of one head with two eyes, a body with two wings and one tail, and two legs. The head has one degrees of freedom enabling it to turn left and right. The beak and each wing has one degree of freedom to move up and down. The legs of the robot have two degrees of freedom allowing to move forward/backward and turn left/right. Two Ai-ball wireless cameras and one USB camera were used to achieve almost 270-degree field of vision. In addition to achieve real-time video transmission, the robot platform is capable of recognizing alphabets and number through use of QR codes. The robot is capable of recognizing English alphabets from A through Z and Arabic numerals from 0 through 9 using the QR code scanning algorithm. Seven touch sensors were used to recognize the tactile interaction preferences of children with KiliRo robot. These sensors were connected in serial to ensure touch of any sensor would enable the LED light on the robot to glow encouraging the children for more physical interaction with KiliRo. When a number or an alphabet was shown to the robot, it reads the QR code pasted in the model and the corresponding text is converted into speech using text-to-speech module.

Figure 1. KiliRo – Schematic diagram.
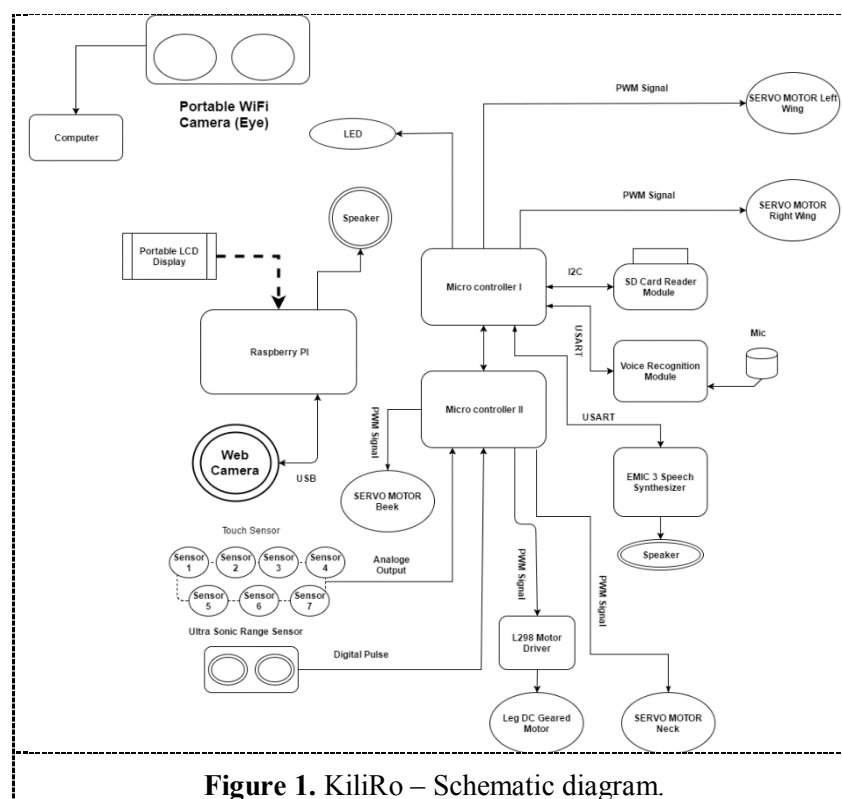
Two Arduino family of microcontrollers and one raspberry pi-3 boards were used to synthesize a range of autonomous behaviours on KiliRo including, speech recognition, object recognition, real-time video transmission, text-to-speech, speaker, microphone, and locomotion gaits. Speech recognition module enabled the robot to recognize 'yes' and 'no' from the participants' and act accordingly. This feature encouraged the participating children to have verbal communication with our KiliRo robot. The speech recognition feature was used to initiate and terminate the robot's speaking module. For instance, when 'Start' was recognized, the robot started introducing itself and when 'Stop' was

recognized, the robot stopped talking. Bipedal mechanism was used for synthesizing the robot locomotion. The robot was able to walk forward, backward, and turn left and right using a pair of DC motors powered using a 2000mAh lithium polymer battery. For the experiments presented in this study, KiliRo's locomotion was achieved using an android application installed on a smart phone. Fig. 2 illustrates our KiliRo robot used in this study.

Figure 2. KiliRo robot.
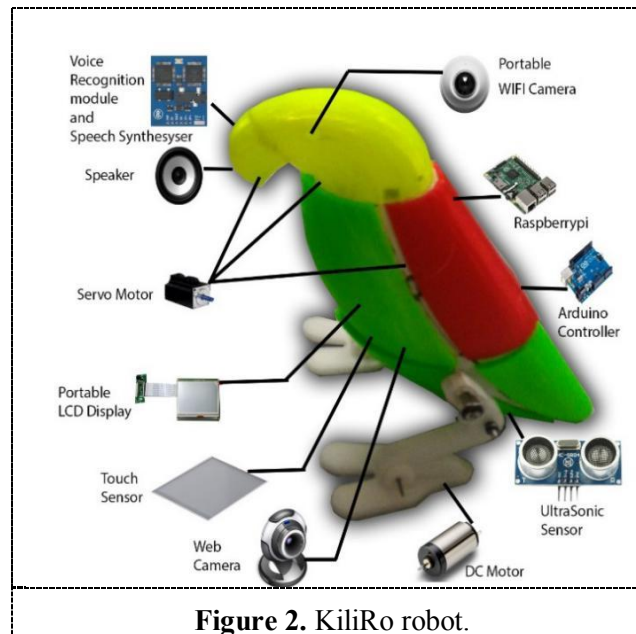
4. Results
Table.1 show the protein and alpha-amylase levels of participants before and after interacting with the robot.

Table 1. Urinary and salivary test results.

Participant number	Protein (mg/dL) (Reference range 0 – 20)		Alpha-amylase (U/L) (Reference range 59 – 401)	
	Before	After	Before	After
1	69.7	19.8	564	98
2	22.5	8.4	179	76
3	29.5	18.8	348	132
4	32.9	25.0	218	121
5	19.0	10.4	113	131
6	22.5	13.4	177	81
7	85.2	26.0	541	420

In our trials, we observed that the average protein level of participating children dropped from 40.19 to 17.40 after interacting with our KiliRo robot. These changes were statistically significant according to a related-samples Wilcoxon Signed Ranks Test (z=-2.37, p<.05). The obtained results clearly demonstrate the efficacy and validity of our developed KiliRo robot in lowering the stress level of children with autism through close human robot interactions.

It is also noted that the alpha-amylase levels have reduced in the second sample test report, from a mean of 305.71 to 151.29. Despite the fact that the level for participant 5 increased at the second time

point, the overall reduction in the alpha-amylase levels of the group was statistically significant (related-samples Wilcoxon Signed Ranks Test, z=- 2.20, p <.05).

The results points to high degree of reduction in stress levels of children with ASD through reduced protein and alpha-amylase levels. All children participated in the study has shown reduction in both substances investigated. Such results are more encouraging to explore robot-assisted therapy among children with ASD.

5. Conclusions

We have developed a parrot-inspired robot, KiliRo and validated the merits of our robot in reducing stress levels and improving physiological conditions with a group of seven children identified with autism over a period of 49 days. We investigated the changes in stress levels of participating children after interacting with the robot through urinary and salivary tests. This is the first time in human-robot interaction study to use salivary sample investigating the changes in stress levels. The urinary and salivary test reports from our study indicated reduction in stress levels among the participants after interacting with our KiliRo robot.

This study has several limitation. Although the results show significant reduction in stress levels of participating children, the study did not have a control group to compare the results. Even though protein and alpha-amylase levels indicate reduction in stress levels of participants after interacting with the robot, several other factors that may have influenced these chemical substances such as, medication, body temperature, personal or cultural activity, and sample taken time. Also the sample size was too low to generalize the findings of the study. Hence, the results of the study should be viewed carefully, and replication with large sample size and control group is needed. With this, we foster to run an extended study with a large target population of minimum 100 people with a control group to compare the findings. Another possibility of future work is to conduct a study with longer duration of over several months. The third area of our interest is to build on our present work and run cross country study at three different locations; India, Singapore, and New Zealand to compare the results. Finally, we intend to extent the autonomous and locomotion capabilities of our KiliRo robot with increased autonomous functions.

References

[1]   Autism Rescue Angels [Internet]. Autism Facts and Statistics. Autism Rescue Angels; 2015 [cited 2016Oct24]. Available from: http://autismrescueangels.org/resources/

[2]   Stanton CM, Kahn PH, Severson RL, Ruckert JH, Gill BT. Robotic animals might aid in the social development of children with autism. In *Human-Robot Interaction (HRI),* 2008 3rd ACM/IEEE International Conference on 2008 Mar 12 (pp. 271-278). IEEE.

[3]   Yu R, Hui E, Lee J, Poon D, Ng A, Sit K, Ip K, Yeung F, Wong M, Shibata T, Woo J. Use of a therapeutic, socially assistive pet robot (PARO) in improving mood and stimulating social interaction and communication for people with dementia: Study protocol for a randomized controlled trial. *JMIR research protocols*. 2015 Apr; 4(2).

[4]   Wada K, Shibata T. Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house. *IEEE Transactions on Robotics*. 2007 Oct; 23(5):972-80.

[5]   Bharatharaj J, Huang L, Al-Jumaily A. Bio-inspired therapeutic pet robots: Review and future direction. In Information, Communications and Signal Processing (ICICS), 2015 10th International Conference on 2015 Dec 2 (pp. 1-5). IEEE.

[6]   Vanderborght B, Simut R, Saldien J, Pop C, Rusu AS, Pintea S, Lefeber D, David DO. Using the social robot probo as a social story telling agent for children with ASD. Interaction Studies. 2012 Jan 1; 13(3):348-72.

[7]   Shamsuddin S, Yussof H, Ismail L, Hanapiah FA, Mohamed S, Piah HA, Zahari NI. Initial response of autistic children in human-robot interaction therapy with humanoid robot NAO.

InSignal Processing and its Applications (CSPA), 2012 IEEE 8th International Colloquium on 2012 Mar 23 (pp. 188-193). IEEE.

[8] Tapus A, Peca A, Aly A, Pop C, Jisa L, Pintea S, Rusu AS, David DO. Children with autism social engagement in interaction with Nao, an imitative robot: A series of single case experiments. Interaction studies. 2012 Jan 1; 13(3):315-47.

[9] Richeson NE. Effects of animal-assisted therapy on agitated behaviors and social interactions of older adults with dementia. American Journal of Alzheimer's Disease & Other Dementias®. 2003 Nov; 18(6):353-8.

[10] Perkins J, Bartlett H, Travers C, Rand J. Dog‐assisted therapy for older people with dementia: A review. Australasian Journal on Ageing. 2008 Dec 1; 27(4):177-82.

[11] Knisely JS, Barker SB, Barker RT. Research on benefits of canine-assisted therapy for adults in nonmilitary settings. US Army Med Dep J. 2012 Apr 1:30-7.

[12] Fine AH, editor. Handbook on animal-assisted therapy: Theoretical foundations and guidelines for practice. Academic Press; 2010 Sep 21.

[13] Levinson BM. Human/companion animal therapy. Journal of Contemporary Psychotherapy. 1984 Sep 1; 14(2):131-44.

[14] Iannuzzi D, Rowan AN. Ethical issues in animal-assisted therapy programs. Anthrozooes. 1991 Sep 1; 4(3):154-63.

[15] Bharatharaj J, Kumar SS. Considerations in Autism therapy using robotics. In Computing, Communications and Networking Technologies (ICCCNT), 2013 Fourth International Conference on 2013 Jul 4 (pp. 1-5). IEEE.

[16] Wada K, Shibata T. Robot therapy in a care house-results of case studies. In Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on 2006 Sep 6 (pp. 581-586). IEEE.

[17] Bharatharaj J, Huang L, Mohan RE, Al-Jumaily A, Krägeloh C. Robot-Assisted Therapy for Learning and Social Interaction of Children with Autism Spectrum Disorder. Robotics. 2017 Mar 14; 6(1):4.

[18] Smith D. A thinking bird or just another birdbrain. The New York Times. 1999 Oct: 1.

[19] Parrots Used in PTSD Therapy for War Veterans. Retrieved September 10, 2016, from http://www.npr.org/templates/story/story.php?storyId=11989027.

[20] Haw C. Parrots as therapy for psychiatric patients. The Psychiatrist. 2007 Apr 1; 31(4):154-5.

[21] Therapy Birds: "Emotional Support Animal. Retrieved September 10, 2016, from http://www.birdchannel.com/therapy-pet-birds.aspx

[22] Parrots As Animal Assisted Therapy [Internet]. For Parrots: Posters for Parrot Advocates. 2013 [cited 2017May10]. Available from: http://www.forparrots.com/2013/09/07/parrots-as-animal-assisted-therapy/.

[23] Smith KA, Bradley KK, Stobierski MG, Tengelsen LA. Compendium of measures to control Chlamydophila psittaci (formerly Chlamydia psittaci) infection among humans (psittacosis) and pet birds, 2005. Journal of the American Veterinary Medical Association. 2005 Feb 15; 226(4):532-9.

[24] Wada K, Shibata T. Living with seal robots in a care house-evaluations of social and physiological influences. In Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on 2006 Oct 9 (pp. 4940-4945). IEEE.

[25] Phillips N. 24-hour Urine Protein Test [Internet]. Healthline. Healthline Media; 2016 [cited 2017May10]. Available from: http://www.healthline.com/health/24-hour-urine-protein

[26] van Stegeren A, Rohleder N, Everaerd W, Wolf OT. Salivary alpha amylase as marker for adrenergic activity during stress: effect of betablockade. Psychoneuroendocrinology. 2006 Jan 31; 31(1):137-41.

[27] Rohleder N, Nater UM, Wolf JM, Ehlert U, Kirschbaum C. Psychosocial stress‐induced activation of salivary alpha‐amylase: an indicator of sympathetic activity?. Annals of the New York Academy of Sciences. 2004 Dec 1; 1032(1):258-63.