Response Patterns during Child-Robot Interaction of Children with Cognitive Impairments

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***Abstract*—Literature on Human-Robot Interaction reports that children with cognitive impairments often have engaging interactions with social robots. However, there are hardly any guidelines on how to design an interaction to achieve particular therapeutic outcomes. This paper reports on a study in which 20 children with cognitive impairments interacted with a social robot, with the aim to assess their responses and their engagement which eventually impacts on the outcomes we can achieve. The children were introduced to the robot and had three sessions during which they played therapeutic games with the robot to improve their attention skills. The overall pattern of their responses for in the sessions are reported, showing a reduction in completion time with each subsequent session. This is indicative of improved attention. This response pattern might be important in future behaviour analysis, especially as a measure for social attention skills, eye contact, and engagement analysis during child-robot interaction.**

Keywords–Robot, Cognitive Impairments, Child-Robot Interaction

I. INTRODUCTION

Robots have been actively used in recent years to help children with cognitive and physical disabilities and other special needs. Research suggest that children positively engage with robots during child-robot interaction, e.g. [1], [2]. According to some carers and teachers, children with cognitive impairments (hereafter referred to as "CWCI") are known to have difficulties with remaining focused during human-human interaction, which in turn has a negative impact on interactions with peers, teachers and family members.

Conventional human-human intervention programs and therapy were proven to be effective to improve their social communication skills [3]. Teachers and therapists usually rely on additional tools, such as cards or toys, for their intervention programs or therapy sessions. Given the reliance on external props to support the sessions, and the need for focal points to practice social skills such as joint attention, deictic gaze and eye contact, it likely that social robotics can play a role here.

In this study, we use the social robot LUCA (as illustrated in Figure 1) and designed child-robot interaction modules to help CWCI to improve their social interaction skills. We hypothesize that their response towards the robot and the interaction modules shall provide us with more information and insight with which to design future child-robot interaction studies. Section 2 discusses the experimental study of our child-robot interaction, together with a description of each module. Finally, section 3 shall reports the finding of the study which elaborate the pattern of child's response in each module for each session of child-robot interaction.

Figure 1. Figure shows LUCA robot which was build based on OPSORO robot platform [4].

II. CHILD-ROBOT INTERACTION EXPERIMENT

All experimental procedure has been given ethical approval on 30th July 2018 from Research Ethics Committee, Universiti Teknologi MARA (UiTM), Malaysia (REC reference number: 600-IRMI (5/1/6)). In this study, we collaborated with one of the schools in Putrajaya, Malaysia. This school has 92 children with special needs. 20 children diagnosed with cognitive impairments fulfilled our inclusion and exclusion criteria as described in Table I.

Consent to participate in our study was also obtained from their parents or legal guardian prior to start the experiment. The protocol of the experiment was clearly explained to the teachers and therapist. A teacher or therapist would come to the experimental room with one child at a time. They would knock on the door, walk into the room and sit down in front of the robot. All interactions were recorded using five video cameras for later analyses. Once the child was seated and ready, the teacher would flash a card at the robot and the interaction with the robot was initiated. Each child was exposed to the robot for 3 consecutive sessions. Each session consists of 5

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TABLE I. INCLUSION AND EXCLUSION CRITERIA FOR ALL PARTICIPANTS

Inclusion criteria	Exclusion criteria
1)Age between 6 to 12 years	1)Child with mutism
2)No evidence of self injury or aggressive behaviour	2)Uncorrected hearing deficit
3)Able to speak in English or Malay	3)Uncorrected vision deficit
4)Diagnosed as having a Cognitive Impairment (level validated by attention skills via Children Colouring Trail Test: CCTT [5])	4)Unwillingness to participate
5)Able to follow simple instructions in English or Malay	

interaction modules. The 5 modules are as below:

- **Module 1: Introduction to the robot**
  The first module aimed to introduce the robot to the participant. The child was welcomed by LUCA using simple English language and some low valence non-verbal behaviour. The text to speech voice was generated using an online synthesize [6].
- **Module 2: Facial expression game**
  This module was designed as a facial expression game and has been designed to help CWCI improve their attention skills [7], [8]. The dependent variable in this module is the time taken by the child to complete the task. In this module, the researcher controlled the robot and selected a range of different facial expressions such as happy, sad, angry. The children were invited by the robot to guess the expression, and they were allowed a second try if their initial answer was wrong. If their answer was still incorrect, the correct answer was given by the robot. The children were also expected to mimic the expression of the robot while maintaining eye contact with the robot.
- **Module 3: Song with facial expression game**
  In this module, a song was added to the facial expression game in order to encourage the children to play the facial expression game and make the interaction more engaging. Some children have some difficulties in distinguishing certain facial expressions. The music was chosen to match the emotions expressed by the robot and helped the children guess the facial expression, next to enhancing their attention span.
- **Module 4: Attention task**
  This module was developed to measure the attention skills of the child. These are very important skills, central to social interaction, learning and collaboration, and robots are believed to be able to improve these skills during Child-Robot Interaction [9], [10]. This session expected the child to look at a certain shape pasted on a board placed on the right (for example, an image of rectangle) and left (for example, an image of circle) of the robot. The child would need to perform a "matching task" in which the robot gave an instruction to look at at a shape (mounted to the left or right of the robot) and fixate their gaze for 3 seconds. For example, he/she would be required to look at the rectangle for 3 seconds.
- **Module 5: Free style interaction**
  Finally, module 5 was a free style interaction between the child and the robot. The child was given the chance to ask questions to the robot. The robot answered, with answers being typed in on a keyboard by a member of the research team and spoken by the robot. If children requested the robot to move, then these actions were performed when the robot had the capability to do so.

III. RESULTS

This section reports on the overall response to the child-robot interaction for children diagnosed with cognitive impairments. Five modules were designed for this study. In module 1, children were only introduced to the robot. This is necessary in order to break the ice between the child and the robot [11], [12] and to assure the following interactions are not influenced by the child being unfamiliar with the robot or the study setting. Neither behaviour nor tasks in module 1 have been evaluated. Nevertheless, the average response time from all children was recorded to be around 60 seconds as shown in Fig. 2. In module 2, the overall response pattern showed that children took less time to complete the tasks in session 2 and 3 as compared to their average completion time in session 1. This pattern suggests that their level of concentration and attention skills has improved, considering they take less time to complete the modules over the 3 consecutive sessions. This however needs to be further investigated, as a reduction in completion time might also be caused by a practice effect.

In module 3, the overall response pattern of the children were similar to those in module 2. There was a slight improvement between session 2 and 3, as the addition of music in session 3 had a positive impact on task completion time. Earlier pilots and studies also found that music was an effective manner to draw children into the interaction [12], [13]. In module 4, there was only a slight improvement in the time needed to complete the tasks. Most of the children needed less time to complete the task in session 2 and 3 as compared to session 1, which we expected since the task were uncomplicated. Finally, the results for module 5 were difficult to generalize since it was an open and free style of interaction. The pattern for the children's response in 3 different sessions were quite scattered. This module can be very useful to gauge their interest in and attention towards the robot, which serves as a measure for their focus in social interactions [14], [15]. Their overall response varies in each session. Nevertheless, we show how unstructured interactions are still able to capture the attention of the children, with most children engaging with the robot. Most of the children showed their interest towards the robot and spent an average approximately 2 minutes in all session.

IV. CONCLUSION

We showed that children diagnosed with cognitive impairments respond well to child-robot interaction. Based on our observations, they spent an enjoyable time interacting with the LUCA robot. The tasks set by the robot were designed to uncomplicated and motivated the children to keep interacting

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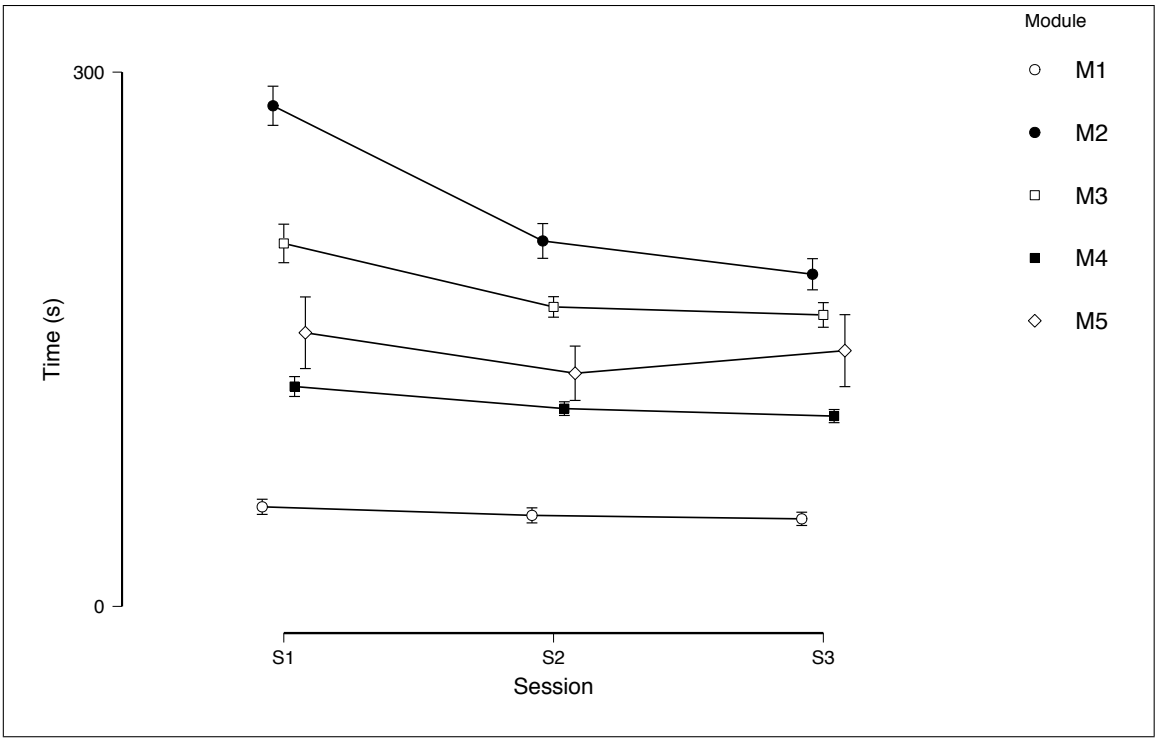

Figure 2. Figure shows the overall results of child-robot interaction time for each module in Session 1, 2 and 3.

with the robot, with no children expressing or showing disappointment with the robot. The child-robot interaction modules hold promise to help children with cognitive impairments to improve their social interaction skills. While our initial results are encouraging, further analysis is needed, especially with regards to improving the children's attention skills and transfer to human-human interaction. Time completion task analysis could be used as a proxy to indicate their improvements in attention skills in modules 2, 3 and 4 for each session. Moreover, interaction duration time could also be used as a proxy to measure their interest in the robot in module 5. This can be useful, especially for future behavior monitoring by a therapist or carer. Completion times could provide important information about the behaviour of children diagnosed with cognitive impairments (such as eye contact patterns and level of attention skills) in child-robot interaction.

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REFERENCES

[1] L. I. Ismail, S. Shamsudin, H. Yussof, F. A. Hanapiah, and N. I. Zahari, "Robot-based intervention program for autistic children with humanoid robot nao: initial response in stereotyped behavior," Procedia Engineering, vol. 41, 2012, pp. 1441–1447.

[2] T. Belpaeme, P. Baxter, R. Read, R. Wood, H. Cuayáhuitl, B. Kiefer, S. Racioppa, I. Kruijff-Korbayová, G. Athanasopoulos, V. Enescu et al., "Multimodal child-robot interaction: Building social bonds," Journal of Human-Robot Interaction, vol. 1, no. 2, 2013, pp. 33–53.

[3] J. A. Corbett, M. R. Trimble, and T. C. Nichol, "Behavioral and cognitive impairments in children with epilepsy: the long-term effects of anticonvulsant therapy," Journal of the American Academy of Child Psychiatry, vol. 24, no. 1, 1985, pp. 17–23.

[4] T. Vervisch, N. Doms, S. Descamps, C. Vandevelde, S. Verstockt, J. Saldien et al., "Oto–a diy platform for mobile social robots in education," in International Conference on Robotics and Education RiE 2017. Springer, 2017, pp. 257–262.

[5] A. M. Llorente, R. G. Voigt, J. Williams, J. K. Frailey, P. Satz, and L. F. DElia, "Children's color trails test 1 & 2: test–retest reliability and factorial validity," The Clinical Neuropsychologist, vol. 23, no. 4, 2009, pp. 645–660.

[6] I. Cloud. Text to speech. Accessed on July to August 2018. [Online]. Available: https://text-to-speech-demo.ng.bluemix.net/

[7] A. G. Pour, A. Taheri, M. Alemi, and A. Meghdari, "Human–robot facial expression reciprocal interaction platform: case studies on children with autism," International Journal of Social Robotics, vol. 10, no. 2, 2018, pp. 179–198.

[8] A. Adams and P. Robinson, "An android head for social-emotional intervention for children with autism spectrum conditions," in Affective Computing and Intelligent Interaction. Springer, 2011, pp. 183–190.

[9] C.-M. Huang and A. L. Thomaz, "Joint attention in human-robot interaction." in AAAI Fall Symposium: Dialog with Robots, 2010.

 ISBN: 978-1-61208-725-2

[10] Z. E. Warren, Z. Zheng, A. R. Swanson, E. Bekele, L. Zhang, J. A. Crittendon, A. F. Weitlauf, and N. Sarkar, "Can robotic interaction improve joint attention skills?" Journal of autism and developmental disorders, vol. 45, no. 11, 2015, pp. 3726–3734.

[11] N. Bee, E. André, and S. Tober, "Breaking the ice in human-agent communication: Eye-gaze based initiation of contact with an embodied conversational agent," in International Workshop on Intelligent Virtual Agents. Springer, 2009, pp. 229–242.

[12] L. I. Ismail, S. Shamsudin, H. Yussof, F. A. Hanapiah, and N. I. Zahari, "Estimation of concentration by eye contact measurement in robot–based intervention program with autistic children," Procedia Engineering, vol. 41, 2012, pp. 1548–1552.

[13] Y.-H. Peng, C.-W. Lin, N. M. Mayer, and M.-L. Wang, "Using a humanoid robot for music therapy with autistic children," in Automatic Control Conference (CACS), 2014 CACS International. IEEE, 2014, pp. 156–160.

[14] K. Dautenhahn, "Robots as social actors: Aurora and the case of autism," in Proc. CT99, The Third International Cognitive Technology Conference, August, San Francisco, vol. 359, 1999, p. 374.

[15] ——, "Methodology & themes of human-robot interaction: A growing research field," International Journal of Advanced Robotic Systems, vol. 4, no. 1, 2007, p. 15.

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