Humanoid Robot NAO as HRI Mediator to Teach Emotions using Game-centered Approach for Children with Autism

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Abstract—This short report presents the latest development in our robot-based intervention program for children with autism. Following the outcome from our first pilot study; the aim of this current experiment is to explore the application of NAO robot to engage with a child and further teach about emotions through a game-centered and song-based approach. The children participating in this study has been diagnosed with mild autism. Initial exposure to the robot shows that the NAO robot; a humanoid with moderate likelihood to actual human does have potential to teach children with autism about head and body postures that are associated with certain feelings or emotions. Overall observation suggests the positive utilization of robots, specifically the humanoid robot NAO in the rehabilitation of autistic children.

Index Terms—humanoid robot NAO, autism, human-robot interaction (HRI)

I. INTRODUCTION

The advent and availability of affordable robots have empowered the researchers in robotics community to delve further in studies on human-robot interaction (HRI). HRI is an evolving juncture of research where intelligent robots improve the quality of human lives by providing support in social and behavioral engagements, whilst protecting the safety of both entities. Specifically for children with developmental disorders, robots can offer engaging personal experience as it is effectively motivating, accurate, objective, adaptive and may even enable therapy to be carried out at home for the disabled.

Autism is a complex neurodevelopmental disorder which affects a person’s behavior, social interaction and communication skills. Diagnosed prior to the age of three years; autism usually lasts throughout a person’s lifetime. Early intervention is critical for the children inflicted with autism \cite{1} in order for them to lead productive lives with a higher degree of independence in their future years.

Research evidences are accumulating on how robots and HRI are able to improve the outlook of children inflicted with autism. Positive responses have been reported where robots are a part of therapy to aid the children in areas of social skills \cite{2-4}, communication \cite{5-7} and even act as playful companions \cite{8} among others. As gathered by Baron-Cohen \cite{9} and supported by Pierno \textit{et al} \cite{10}; people with autism cannot cope with systems of high variance such as social behavior, conversation and human emotions. Hence, robots which are simpler in appearance offer minimal variance and simpler stimuli that are able to attract responses from these children to engage in interaction.

The fundamental purpose of HRI is the development of robot systems that are capable of direct, safe and effective interaction with humans \cite{11}. Following this guideline, the NAO program in this study has been tailored to be simple yet meaningful, enjoyable (embedding music element) and safe by maintaining a specified distance of 60 centimeters between child and robot throughout the duration of interaction. The suggested safe working area for NAO is shown in Figure 1.

The aim of this study is to explore the response of two autistic children to a humanoid robot NAO that has been programmed to display 5 different emotions using its body poses and gestures. The interaction begins with an

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{Fig1.png}
\caption{The safe area of workspace for NAO robot \cite{12}}
\end{figure}
introductory module that embeds two-way communication between the child and robot. This is followed by Module 2 that teaches emotions (hungry, happy, mad, scared, love/hug) and the third module that adopts the guessing game approach in relation to the contents in the second module. The final module consists of NAO playing a popular nursery song ‘Twinkle twinkle little star’ and moving its hands in accordance to the melody.

It is a known fact that children with autism have difficulties in recognizing expressive facial emotions [13]. Therefore we wish to investigate the hypothesis that a humanoid robot with a moderate degree of likeness to an actual human [14] is able to portray and teach emotions to autistic children. This will be explored through the game-based approach which had been tested in preceding literature [8, 15] where a humanoid robotic doll had been used, resulting with meaningful human-robot interaction as well as human-human interaction. Also, the children had enjoyed playing imitation games with the robot. This allowed them the exposure to the interaction space where robots act as objects of shared attention thus promoting social and communication skills.

II. CONTENT OF GAMING MODULES

The complete NAO program reported in this study consists of 4 separate modules. A ten-second break after each module is allocated to allow interval between each unit of interaction. The fixed distance between child and robot has been tested prior to the experiment to ensure that the child can hear the voice and sound from NAO clearly and vice versa which is paramount for two-way communication.

As a continuity from our pilot study with autistic children [16, 17] where encouraging responses have been recorded; our team decided to embed some aspects from the previous interaction modules into the current study in Module 1 and Module 2. From our previous research, we had documented that NAO’s simple appearance compared to actual humans is able to act as a pull-factor to ignite the child’s interest to sustain interaction. Furthermore, NAO’s capability to have multihued eye colors, talk and play music adds up to make it a promising platform in teaching the children with ASD to initiate joint attention with the robot which later on would expand to include fellow peers and people around them.

The interaction content in Module 1 focuses on two-way communication between child and NAO which was not included in the previous pilot study. Acting as the introductory rapport; NAO (in standing-up position) starts by introducing itself followed by 3 simple questions that require response or answers from the participants: 1) ‘May I sit down?’, 2) ‘What is your favorite color?’ and 3) ‘Do you like going to school?’ As mentioned in [18], children with autism thrives in verbal communication with robots and hence are able to engage affectively in interaction.

Module 2 and Module 3 showcases the prime aim of the study; which is for the children to learn from NAO about emotions that are portrayed through the robot’s body posture acts. The emotions are hungry, happy, mad, scared and love/hug as shown by pictures in Figure 2. In Module 2 the emotions were shown consequently through a story told by NAO. Each emotion beginning with ‘hungry’ and finally ‘love/hug’ were shown through the robot’s body gestures and pronounced clearly by the robot. This was followed by a recap summary of all the emotions to help the child memorize.

Then in Module 3, NAO conducts the guessing game where body postures in Module 2 are repeated one by one for the participant to guess the correct associated emotion. For every correct answer given, NAO shall praise the child by saying ‘You are brilliant!’ as a form of verbal reward.

In the final module, NAO plays a popular nursery song ‘Twinkle twinkle little star’ while moving its hands in accordance to the melody. The same song has been utilized in our first pilot study and gathered from the previous responses; most children are familiar with this song. Using a popular rhyme plus the added attraction of NAO carrying out hand and arm movements in accordance to the melody, we expect that the child-robot ‘engagement’ since Module 1 can be sustained. We further anticipate that without given prior instructions, the children would imitate the robot’s movements. Furthermore, the song also acts as closure and ending to the whole interaction. Figure 3 shows the flow of modules in this experiment.

III. ROBOTIC ARBITRATOR

The humanoid robot NAO offers a robotic platform with simple, moderate features compared to real humans. Even though both humanoids and non-humanoid robots have used and integrated into autism therapy; humanoids do work better in imitation-based scenarios [19].
Hence in this paper we intend to present the humanoid robot NAO as an interaction arbitrator with the capability to physically display emotions. This shall entice the child with autism to recognize the different state of emotions. Later on, their understanding on the association of emotions with simple body gestures can be developed.

Each of the five emotions shown by NAO’s body gestures are displayed to the children in a short story. The storytelling approach using NAO has been studied in [20] as an agent capable of expressive behavior. With NAO acting as the platform to attract the children’s attention and engage in interaction; the guessing game approach in Module 3 is adopted to create an enjoyable learning scenario for the children to pick up the emotions shown by NAO.

The modules were designed and the developed using Choregraphe software. Snapshots from the programming stage are shown in Figure 4.

IV. EXPERIMENTAL SET-UP

The study had been carried out at a day-care center in Shah Alam, Malaysia that provides special care for children with disabilities. The classroom that we use to carry out the experiment has been divided into two areas: the experimenter station and the child-robot interaction area.

During the experiment, each child will be accompanied by his own teacher who acts as a ‘comforting presence’ to the child. Visual and sounds during the child-robot interaction were recorded via 2 external HD video cameras and 1 mini video camera positioned on NAO’s body. NAO is positioned to be facing the child throughout the interaction. In the set-up, the experimenter will not be visible to the children and the teacher (hidden from view). At the experimenter station, video streams from the three video cameras are observed through television monitors. The full set-up is shown in Figure 5.

The participants in this study are child HH who is 7 and child KA aged 9. Both children are male and have been diagnosed with mild autism. To suit the aim of this study, we have set-up a list of selection criteria for children who wish to participate. Other than having autism diagnosis, the child must also have no deficits in hearing and vision, no nystagmus and no self-injury. The child must also be able to understand, speak and follow simple commands in English.

V. OBSERVATIONS FROM PRELIMINARY TRIAL

The initial trial both children have been video recorded and the video data are currently being analyzed. We adopt the same behavior score sheet (referenced to The Gilliam Autism Rating Scale (GARS-2) and previously elaborated in [17]) to assess the videos. Detailed results will be published in forthcoming publications. Nevertheless, the following observations has been noted by the first author and described according the responses by each child:

Child HH is a quiet boy who usually avoids eye contact. Prior to the start of the experiment, he was smiling and expectantly looking at the robot. In Module 1, he gave correct responses to NAO and looked directly at NAO when NAO was conversing with him. Module 2 and Module 3 witnessed child HH correctly guessed all the five emotions shown by NAO body postures. In the final module, he looked a bit apprehensive at first but then started to slowly imitate NAO’s arms movements as shown in Figure 6. However, he did not look like he was enjoying the song played in Module 4.

Child KA is also a minimally verbal person. He was smiling and looked at ease with the presence of NAO at the beginning of the interaction. During Module 1, he did give attention to NAO when prompted but he also seeks response from his teacher before replying. He enjoys and gave full attention to all postural emotions shown by NAO in Module 2. He too guessed all the five emotions correctly whilst fully
imitating NAO posture when prompted to guess the ‘scared’ pose. Contrarily to his peer’s response in Module 4, child KA readily imitate and enjoys NAO’s movements when the song ‘Twinkle twinkle little star’ was being played though the robot’s own speakers.

Both children had successfully guessed the emotions shown by NAO in Module 3. Based on a verbal interview with his teacher two days after the interaction with NAO, child HH had significantly smiled more often and noted to voluntarily talks more especially about his experience with the NAO robot. For child KA, he also had been noted to show increase in verbal conversation whilst expressing high interest to the humanoid robot NAO.

VI. CONCLUSION

Overall preliminary results suggest that the game-based approach for the children participating in this study to learn, understand and correctly guess the emotions shown by NAO has been a success. Hence, a humanoid with moderate likelihood to actual human does have potential to teach children with autism about head and body postures that are associated with certain feelings or emotions. Consequently, a robot in human shape is a salient mediator to teach emotions to the children and this can easily be transferred from child-robot to human-human interaction in actual social scenarios.

It is worth mentioning that particularly for child HH, the arm movements of the robot in accordance to the song were not simple enough for him to follow and imitate. Nevertheless, this did not hinder him from trying to follow the arm movements by the robot NAO. Hence, for Module 4 specifically, we are able to provide proof that the robot was able to attract the children’s attention and foster meaningful engagement for the children to follow the robot’s arm movements without being asked to do so. Therefore, learning approach using game and common nursery song for children with autism is able to encourage positive and encourages responses from the children.

Also both children were not scared or showed any act of shying away from the robot. Two-way communication between the child and robot in real time significantly give positive impact in the responses towards the robot.

After the initial experiment, the children had also often enquired to their teacher about when they are going to meet and interact with the robot again. Such clear and uninstructed response gave an overall picture on the positive utilization of robots specifically a humanoid with moderate similarity to real humans in the rehabilitation of autistic children.

VII. FUTURE WORKS

An experimental study involving more subjects (of children with autism and typically developing children) is underway. Current modules presented in this study will be improved based on inputs from medical experts. We are also curious on results of contrasting short-term and longitudinal exposure of the humanoid robot NAO to autistic children. This indeed will be explored in the next juncture of our research.

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