Can social robots function as models for children with ASD? An intervention study on joint attention skills

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ABSTRACT
In the last three decades, robots are placed in the picture by media and are becoming more accessible in daily use. They are proposed not only as part of entertainment and education, but also of care, social assistance and therapy. As such, several institutions from industry are buying social assistive robots and start to use them in classrooms or during therapy sessions without having empirical support and thus, no evidence-based protocols to follow. For example, there has been an increasing interest in Robot Assisted Therapy for children with Autism Spectrum Disorder (ASD). While there is much declared as being hopeful and exciting about using robots for treating children with ASD, it will take much research effort before robots become mainstream in intervention. Moreover, experts are advocating caution and express the need to explore the development path of the child-robot relation. This study focused on using a social robot with the role of a *model*, a peer that demonstrated joint attention skills (JA) for three children with ASD during a long-term intervention program. Each participant was exposed to three phases: pre-intervention, Robot Modeling Intervention (RMI), and post-intervention. In each phase, JA behaviors were assessed three times per week in a naturalistic environment, such as their classroom, during the free-play moment. The RMI intervention proved to be effective for some of the targeted behaviors, such as eye contact and pointing, for two of the three participants. However, the results were highly fluctuating across the participants and, thus, they remain inconclusive. However, this study offers a valuable insight in both, ASD treatment and human-robot interaction research fields.

CCS Concepts: Psychology; Children; People with disabilities; Assistive technologies.

Keywords: robot assisted therapy; children with autism spectrum disorder; social robot; joint attention.

1. INTRODUCTION
It is widely accepted that typically developing children learn through observing the behaviors of others and also the consequences of these behaviors. As described in the social learning theory by Bandura [1] modeling is a form of observational learning that requires a social model such as a parent, sibling, peer, or teacher. Particularly in childhood, a model is often someone of authority or someone that is very liked or appreciated.

In atypical development, such as in ASD, research has demonstrated that children do not effortlessly learn by observing the others [2]. They are in generally impaired in skills that may be related with observational learning, such as attending [3] and imitating [4]. Those impairments often hinder children with ASD in identifying models and thus, in learning through observing their social behaviors. This study will focus on using a social robot as a peer that will model joint attention (JA) skills. Peer modeling is declared an effective intervention for social skills in young children with ASD [5] [6] [7], but there are several limitations on the procedures to note. Firstly, it is a very time-consuming and challenging to implement this type of intervention, particularly when the model has a young age, since a lot of preparation and training is necessary to make a peer to be ready to deliver an intervention [7]. Moreover, most of the studies do not report data on how faithfully the peer followed the intervention procedure [7]. Using a social robot, that is both consistent yet flexible, as the "peer" that models the JA skills could answers the limitations listed above. Due to its flexibility, a robot is easily to pre-program and adjust to children's developmental needs. Therefore, a robot-modeling intervention can easily follow a pre-established protocol and be delivered in a standardized way. Moreover, there are other important reasons to be listed for using robots as peers in modeling JA skills for children with ASD. Firstly, majority of children with ASD showed a higher level of motivation in tasks assisted by robots in comparison with traditional tasks with human instructors [8], due to their intrinsic attraction towards technology and mechanical toys. Secondly, a robot can give sensory rewards and feedback, which have shown to be highly beneficial for children with ASD

[9] Thirdly, an increasing number of studies declared already that a social robot can be a suitable tool to elicit JA skills for children with ASD [10] [11]. Fourth, a robot can be constrained in the information it conveys, thereby only communicating relevant information to the child and decreasing the chance that the child gets distressed [12]. Thus, a robot provides a more simplified and predictable learning environment in comparisons with regular peers used in interventions [13].

To conclude, this study aims to improve the observational learning of joint attention skills for children with ASD, by using the strengths of a robotic tool to overcome their attention and social motivation deficits. The assumption is that a social robot has potential to be a good model for showing JA skills for children with ASD.

Based on these strengths of a robotic tool and on research supporting the peer-modeling as an effective intervention, this study addresses, to our knowledge, for one of the first times, the research question: Can a social robot be used as a peer-model for young children with ASD, by following an evidence-based protocol for teaching JA skills [14]?

2. METHOD

Three participants form a special education school were included in a multiple baseline design (MBL) across participants, meeting the following inclusion criteria: (1) a chronological age between 36 and 60 months, (2) a mental age not higher than 42 months; (3) a confirmed diagnose of ASD, (4) JA impairment and (5) no presence of hyperactivity, aggression, extreme fear or restraint of contact with new people or other specific phobias.

After the comprehensive clinical assessment, each participant was exposed to three phases: pre-intervention, RMI intervention, and post-intervention. In each phase, even during the intervention phase, the JA performance of the children was assessed three times per week in a naturalistic environment, in the classroom during the free-play time. The pre-intervention phase included 3 to 12 measurements. The different amounts of measurements per baseline are an inherent aspect of the MBL design. The other two phases included a fix number of measurements: 8 for intervention and 3 for the post-intervention phase. The protocol of the intervention was adjusted from the program “I see what you see, I do what you do” [14]. The social robot Nao was used to model the JA skills and was presented to the children as a child of their age, gender and with similar preferences. The robot was operated in a non-autonomous “Wizard of Oz” approach [15], via a laptop. All participants observed a JA training given by a therapist to Nao, after which the child had to take the place of the robot and also perform the RMI with the human therapist (see Figure 1). The exact same session that was used with Nao as a model was used as a therapy session for the child, but with equivalent materials (e.g.: a blue car in place of a red one). The robot always executed correctly every JA task in order to function as a model for the child. Thus, the child did not interact directly with Nao during the intervention. A single therapy session lasted for about 10 minutes with the robot and about 15 – 20 minutes with the child. The child was provided with feedback (“Well done!” or “Good job!”) by both the therapist and robot.

Figure 1. The Social Robot Nao in interaction with a child with ASD during the intervention. Therapist is in front of the child.

3. RESULTS

The graphics in Appendix describe the performance of every participant on each of the four targeted behaviors*. Since the visual analysis was not conclusive, a statistical analysis is provided in order to drawn clearer outcomes. The Kruskal-Wallis test was used in order to see whether there are significant differences between the three phases of the study. Where a significant difference was obtained, three U Mann Whitney tests were also performed in order to identify where the obtained significant difference is located.

Participant 1. No significant differences were found between the three phases for none of the target behaviours, Eye Contact (χ^2 = .34, p = .84), Alternate (χ^2 = .65, p = .72), Following Line of Regard (χ^2 =3.85, p =. 14), except for the Pointing (χ^2 = 8.03, p = .01). In order to see where exactly this significant difference was positioned, the U Mann-Whitney test was used. When we compared pre-intervention (Mdn=0) with RMI intervention (Mdn=1), we found no significant differences: U = 39.5, Z= -1.10, p = .26. Between group pre-intervention (Mdn=0) with post-intervention (Mdn=4) however, we did find significant differences (U = 0.50, Z= -2.51, p = .01). When we compared RMI intervention (Mdn=1) with post-intervention (Mdn=4), the analyses revealed also significant differences (U= 2.00, Z= -2.38, p = .01).

Participant 2. No significant differences between the three phases were found for none of the target behaviours Alternate (χ^2 = 1.03, p = .60) and Pointing (χ^2 = 3.98, p = .14), Eye Contact (χ^2 = 5.02, p = .08) except for the Following Line of Regard (χ^2 = 6.61, p = .04). When we compared pre-intervention (Mdn=5) with RMI intervention (Mdn=6) for Eye Contact, significant differences are found: U = 36.00, Z = -2.14 p = .03. with a medium effect size (d = .44). Between group pre-intervention (Mdn=5) with post-intervention (Mdn=8) however, we did not find significant differences for Eye Contact (U = 9.00, Z= -1.32, p = .18). When we compared RMI intervention (Mdn=6) with post-intervention (Mdn=8), the analyses revealed no significant differences (U= 17.00, Z= -.15, p = .88). When we compared pre-intervention (Mdn=0) with RMI intervention (Mdn=1,50) for Following Line of Regard, a marginal significant difference is found (U = 42.00, Z = -1.87, p = .06) with a medium effect size (d = 0.38). Between group pre-intervention (Mdn=0) with post-intervention (Mdn=2) however, we find a significant difference (U = 3.00, Z = -2.40, p = .02) with a large effect size (d = .62). When we compared RMI intervention (Mdn=1.50) with post-intervention (Mdn=2), the analyses revealed no significant difference (U = 12.00, Z = -.92, p = .36).

Participant 3. No significant differences between the three phases were obtained for Alternate (χ^2 = 1.19, p = .55) and Pointing (χ^2 = 1.56, p = .46), but on the contrary, a significant difference was revealed for the Eye Contact (χ^2 = 16.01, p = .001) and Following Line of Regard (χ^2 = 9.26, p = .01). When we compared pre-intervention (Mdn=1) with RMI intervention (Mdn=4) for Eye Contact, significant differences are found: U = 36.00, Z = -3.42 p = .001). Between group pre-intervention (Mdn=1) with post-intervention (Mdn=5) also significant differences are found: U = 2.00, Z = -2.63, p = .01 with a large effect size (d = .54). When we compared RMI intervention (Mdn=4) with post-intervention (Mdn=5), the analyses revealed no significant differences (U = 8.50, Z = -1.41, p = .16). When we compared pre-intervention (Mdn=0) with RMI intervention (Mdn=0.5) for Following Line of

Regard no significant difference was found: U = 96.00, Z = -1.34, p = .18. Between group pre-intervention (Mdn=0) with post-intervention (Mdn=2) however, we did find significant differences for (U = 3.00, Z = -2.91, p = .004) with a large effect size (d = .60). When we compared RMI intervention (Mdn=0.5) with post-intervention (Mdn=2), the analyses revealed a significant difference (U = 4.00, Z = -2.16, p = .03).

Additional information of the child-robot interaction

Overall, considering all eight sessions with the robot, the children expressed an increased interest in the robot. They initiated conversations and touched the robot very often. Two of the participants imitated the exact sequence from what the robot said in the intervention protocol (the exact words in the same order and with the specific intonation of Nao) during their free-play time in the classroom. Also, the participants enjoyed receiving feedback from Nao and they were very good in anticipating it. Almost every animation of the robot was accompanied by positive emotional reactions of the participants such as smiling and laughter.

On the other hand, Participant 2 showed anxious behaviors during the introductive session with the robot by covering her eyes and ears when Nao moved or talked. She asked frequently to shut the robot down and it had to be a few meters away from her. Participant 1 and 3 stared during the introduction and were astonished. Participant 1 asked the therapist many questions about the robot such as: “Where does Nao sleep?”, “What does he eat?”, “Can he walk?”. Participant 3 wanted to touch and stroke the robot very often. But, after the first session, all the three participants started to ask questions to Nao such as: “Did I do it well Nao?”, “Would you like to have this toy?”, “Did you see what I did Nao?”, “Do you only have blue clothes?”.

4. DISCUSSION AND CONCLUSIONS

This study aimed to explore the potential of a social robot in modeling joint attention skills for young children with ASD. The outcomes show some improvement in JA behaviors such as eye contact and following line of regard in two of three participants and an improvement of pointing in one participant. However, some JA behaviors did not improve such as alternating gaze and most of pointing. Therefore, we can conclude that the social robot Nao could function as a model for some of JA prerequisites, but not for others. However, more research is necessary with different social robots and different target groups in order to be able to declare that robot modelling intervention is efficient for teaching JA skills to children with ASD.

The findings of this study are consistent with the findings of [10] and [11] where JA skills, noted by eye-gazing, could be elicited with a robot. In two of the three participants, a significant difference between baseline and intervention for eye contact was found. In contrast, these studies used the social robot Nao as an instructor instead of a model and measured JA by the immediate response of the children with ASD towards the robot and not in a naturalistic environment.

There are some important strengths to be mentioned. This study has tried to set up the intervention in a naturalistic environment, by assessing the JA behaviours during free play sessions, which increases the external validity. In addition, the robot mediated intervention was developed based on an evidence-based program for teaching joint attention and imitation [14]. Also, it was organized in a playful context, which increased the motivation of the children [13] Also, this study is unique in exploring a robot as a model for learning JA skills with having the ultimate goal to improve the interaction with the therapist and the peers in the classroom. Most research about robot assisted therapy focused till now at using a robot as a motivating toy or instructor for teaching social skills, but very few of them tried to generalize it with a therapist, caregiver or peers [8].

On the other hand, there are also some shortcomings to mention, such as the small sample of participants, which makes generalization difficult. Group analyses in future research are necessary to see if this innovative approach can be used as a widespread therapy for children with ASD. Another type of limitation consists in the technical limitations due to the use of robots in general. Current hardware of robots is extremely sensitive and can be easily broken. In therapy or in classrooms where children are involved, robots must be resilient to punches, beating, kicking or pushing [8]. Also, most robot systems in autism therapy use the Wizard of Oz method [15], this technique is not useful for widespread robot use. This means a human must control the robot every time, in every therapy session which is very time-consuming and not efficient. Future studies with controllable robots by the therapist with, for example, a joystick, would be an added value for clinical research.

Besides all limitations and although the results were highly fluctuating across the participants, this study offered a valuable insight in the field of both ASD intervention and human-robot interaction research fields.

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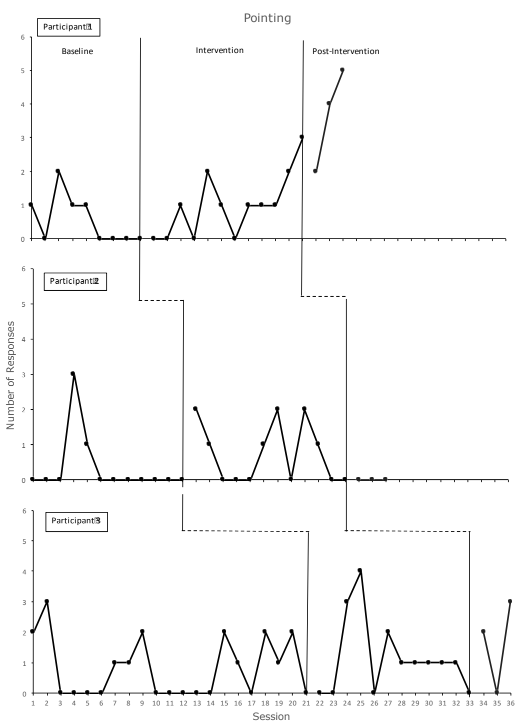
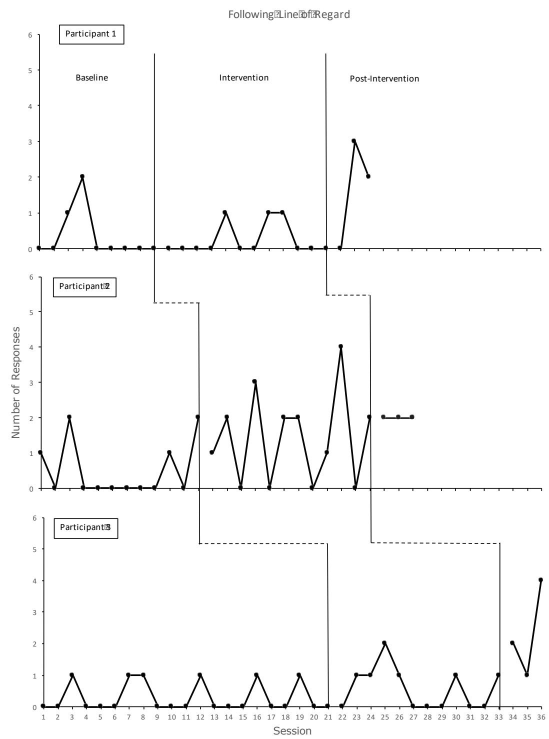
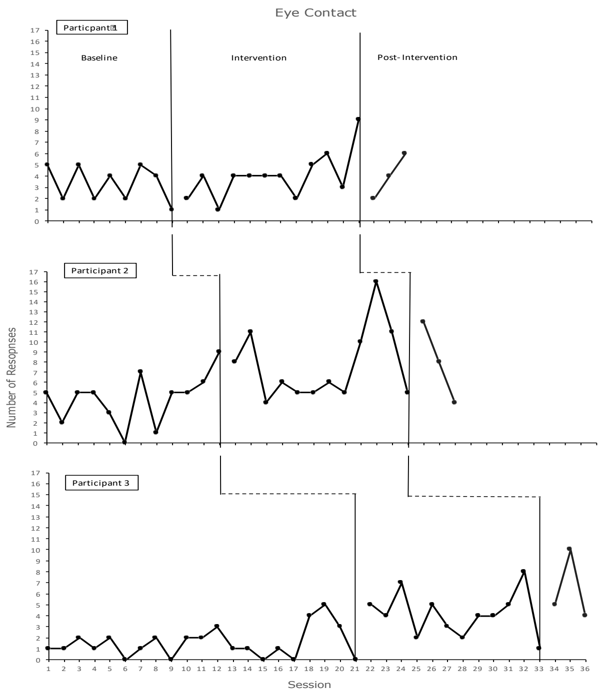
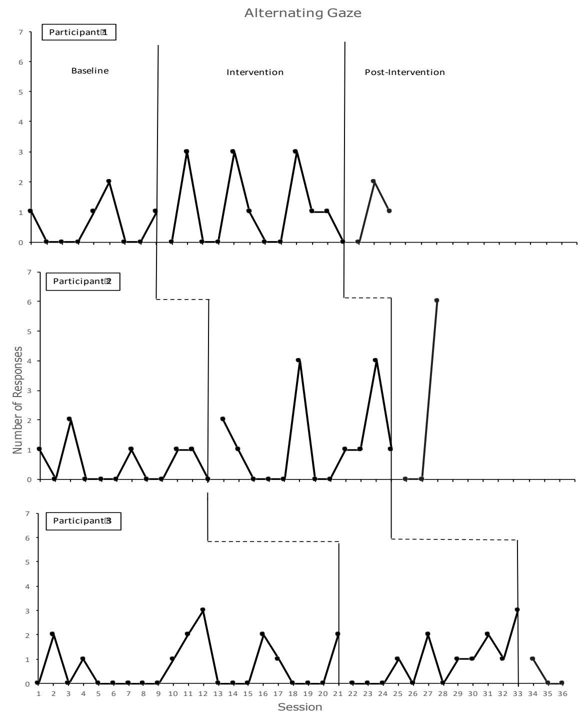
Appendix

The performance of every participant on each of the four targeted JA behaviors:






Eye Contact
Particpant 1
Baseline
Intervention
Post- Intervention
Participant 2
Participant 3
Number of Responses
Session


Alternating Gaze
Participant 1
Baseline
Intervention
Post-Intervention
Participant 2
Participant 3
Number of Responses
Session