A comparison between a person and a robot in the attention, imitation, and repetitive and stereotypical behaviors of children with Autism Spectrum Disorder

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ABSTRACT

The aim of the present study was to assess the usefulness of QT, a socially assistive robot, in interventions with children with autism spectrum disorder (ASD) by assessing children's attention, imitation, and presence of repetitive and stereotyped behaviors. Fifteen children diagnosed with ASD, aged from 4 to 14 years participated in two short interactions, one with a person and one with QT robot. Statistical analyses revealed that children directed more attention towards the robot than to the person, imitated the robot as much as the person, and engaged in fewer repetitive or stereotyped behaviors with the robot than with the person. These results support previous research demonstrating the usefulness of robots in interventions with children with ASD and provide new evidence to the usefulness of robots in reducing repetitive and stereotyped behaviors in children with ASD, which can affect children's learning.

KEYWORDS

ASD, children, robot-assisted therapy, attention, imitation, repetitive and stereotyped behaviors

1 INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by significant difficulties in communication, social interaction, as well as by restricted and repetitive behaviors and interests [1]. ASD is present in approximately 1% of the population [2] and the impact of the deficits can range from mild to severe and impair social, occupational, and functional domains.

People with ASD have a higher prevalence of mental health issues than their neurotypical counterparts as well as people with other disabilities [3,4]. Anger outbursts, self-injurious behaviours, anxiety, and depression are among the main reasons why parents of children with ASD seek professional help [5]. These mental health issues have repercussions into social competence, peer acceptance, adaptive development, and increase the risk of psychiatric diagnoses in adulthood [6,7]. Therefore, teaching social and emotional abilities to children with ASD is fundamental to foster their well-being and the well-being of their families. However, interventions for children with ASD are costly [8] and the services offered are often insufficient or inadequate [9]. To deal with these challenges, the services provided to children with ASD must be made more efficient and the quality should be improved.

Robot-assisted therapy has been proven in the past years to be useful for children with ASD [10]. Socially assistive robots can be beneficial for individuals with ASD because they are rule-based and predictable systems, which can repeat patterns and can be organized and understood in a systematic way. This corresponds to the learning characteristics of children with ASD, who have a desire for sameness and repetition as well as an interest in inanimate objects [1].

Additionally, and in contrast to other technologies (e.g. computer software, tablet applications, virtual environments), interactive physical robots provide embodied multi-modal aspects which are important for interpersonal relations [11]. These characteristics can make interactions with robots more compelling to children with ASD than interactions with a human therapist [11,12]. Additionally, robots provide novel sensory stimuli [13], which can stimulate children's interest and increase assimilation of content.

Previous research has shown the effectiveness of robots in increasing attention [14], joint attention [15], cooperation [16], imitation [17], and communication [18] in people with ASD in comparison to a baseline. However, results regarding whether robots can be at least as effective as people to teach abilities to children with ASD are mixed. Some studies have found that robots are better than humans are at eliciting attention [19,20], joint

[1]Pouyan Ziafati and Aida Nazarikhorram are founders of LuxAI S.A., a social robotic spinoff from the University of Luxembourg. In order to avoid any conflict of interest, they do not participate in parts of this research related to scripting, conducting, testing, analysing, and reporting QT robot applications and experiments for children with ASD.

attention [21], communication [22], and imitation [19,23]. But other studies have found that a robot was as good as a person at eliciting communication [24], joint attention, and motor initiation [25] and that a robot was worse than a person at eliciting imitation of body movements [21] and joint attention [26]. Studying the interaction of children with ASD with robots provides us with valuable information as to whether robots can engage children and be useful teachers to deliver interventions.

A crucial aspect of the behavior of children with ASD has been missing from the previous research on the robots' efficacy with children with ASD – the impact of robots in their repetitive and stereotyped behaviors. Repetitive and stereotyped behaviors are frequent among children with ASD and are thought to induce self-stimulation by creating over-arousal [27] or to act as soothing behaviors by providing an escape from an over-stimulating environment or disturbing inputs [28]. Repetitive and stereotyped behaviors can interfere with learning opportunities [29] and lead to over-selective attention and to difficulties in shifting attention [27], which are fundamental in the learning process.

In the only study that we found reporting on the impact of robots in the repetitive and stereotyped behaviors of children with ASD, it was found that the four children interacting with the robot engaged in fewer repetitive behaviors with their favorite toy and had no repetitive or stereotyped behavior toward the robot [21]. On the one hand, robots are predictable, repetitive systems that can be understood by children with ASD in a systematic way. On the other hand, many children with ASD feel fascinated and excited by meeting a robot. For these reasons, interacting with a robot can provide an arousing experience to a child with ASD while at the same time being less disturbing than an interaction with a person.

In the present study, we aim to test whether QT, a socially assistive robot, can be useful in interventions with children with ASD by assessing whether children's attention and imitation is as good with the robot as with a person. More importantly, we want to assess whether, children's repetitive or stereotyped behaviors are lower in the presence of QT robot than in the presence of a person.

2 METHODS

2.1 Participants

A convenience sample of 15 children previously diagnosed with ASD (all boys), aged 4 to 14 years (M=9.73; SD=3.38), accompanied by at least one of their parents participated in this study. Children's characteristics are described in Table 1.

Participation was open to all children diagnosed with ASD aged from 4 to 16 years. The diagnosis had to be established by an expert in the light of an assessment based on DSM criteria [1] and recognized by the country's health authorities. Diagnoses were confirmed with the Social Responsiveness Scale (SRS; [30]) and IQ was assessed with the Wechsler Nonverbal Scale of Ability (WNV [31]). Participants were part of a larger study on the use of QT robot to teach emotional abilities to children with ASD.

Table 1: Children's characteristics

#	Age	ASD Severity[a]	IQ[b]	Verbal (V) or non-verbal (NV)
1	13.67	Severe	80-120	V
2	8.19	Severe	<80	V
3	13.49	Severe	>120	V
4	4.14	Severe	<80	NV
5	4.54	Mild	<80	NV
6	11.48	Moderate	<80	NV
7	8.85	Severe	80-120	V
8	9.22	Moderate	80-120	V
9	8.21	Severe	<80	V
10	14.46	Severe	80-120	V
11	14.48	Moderate	<80	NV
12	8.22	Severe	80-120	V
13	9.58	Severe	80-120	V
14	6.04	Mild	<80	V
15	11.38	Severe	<80	V

[a]SRS-2 & DSM-5 (Clinical range compatible scales) [30]
[b]Wechsler Nonverbal Scale of Ability-WNV[31]

2.2 Material

2.2.1 Robot. The robot utilized, QT (see Fig. 1), is a commercially available (LuxAI S.A.) child-sized plastic bodied humanoid robot (about 63cm tall and 5kg) used in other recent applications for children with ASD [32]. QT has an expressive social appearance and its screen allows the presentation of animated faces. It has 12 degrees of freedom to present upper-body gestures. Eight degrees of freedom are motor-controlled, two in each shoulder, one in each arm plus pitch and yaw movements of the head. The other four, one in each wrist and one in each hand, are manually configured. QT has a RealSense 3D camera mounted on its forehead and is provided with a microphone array. QT is powered with an Intel NUC processor and Ubuntu 16.04 Lts, and provides a native ROS interface to program it in Python or C++ programming languages. QT also provides a visual programming interface for IT non-experts, used in this study, to easily script custom applications and control the robot by an Android application from tablets and smart phones.

Figure 1: QT robot (LuxAI S.A.)

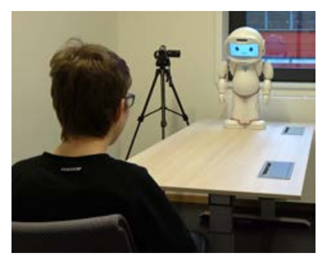

Figure 2: Experiment setup with QT robot

2.2.2 Interview. To compare children's interaction with the robot and with a human, we have created two interviews similar in structure but with different items (A and B). During each interview, the child was sitting at a desk facing the interview partner (QT robot or person; see Fig. 2). Each interview started with the interview partner asking the child his name. Then, the person or the robot presented themselves and asked three questions to the child about his preferences (e.g. favorite animal, favorite color, etc.). Then the interview partner told a short story and asked the child whether he liked the story. To finish, the interview partner asked the child to do an imitation game involving four gestures with the arms (e.g. left arm up, right arm up, left arm to the side, right arm to the side). Interviews lasted between 1.5min to 4.3min (QT: M=3.2; SD=0.58;

Person: $M=2.2$; $SD=0.48$). Children were frontally videotaped during the entire interaction.

2.3 Procedure

Parents and children were invited to participate in the study through a letter distributed by institutions for children with ASD in Luxembourg. The study was reviewed and approved by the university of Luxembourg's ethics review panel (approval number: ERP17-017-SAR-A) and parents read and signed informed consent forms for participation and data collection. The study took place in one 2-hours long visit. During the visit, parents were requested to fill out questionnaires concerning their children. During that time, children were first invited to a room where a person did Interview A with the child. After that, children's IQ was assessed as well as children's emotional ability in different domains. At the end, children were invited to another room where QT robot did Interview B with the child.

2.4 Analysis

The videos of the interviews were coded by one observer. For each child, the observer coded both the child's interview with the person and with the robot. To assess children's attention to the interview partner, the number of children's gazes towards the interview partner and the duration of each gaze was coded. To assess children's imitation of the interview partner's actions, the number of imitations (max. 4 imitations) was coded. Finally, to assess children's repetitive and stereotyped behaviors during the interviews, the number of chains of repetitive and stereotyped behaviors was counted as well as the number of repetitions per chain. A chain of repetitive and stereotyped behaviors was defined as an uninterrupted sequence of the same type of repetitive and stereotyped behavior. If the child paused that behavior to engage in a different behavior, it was counted as one chain. If the child, after the pause, engaged again in the same or in a different repetitive and stereotyped behavior, it was counted as a second chain.

3 RESULTS

The non-parametric Wilcoxon signed-rank test was used to compare children's attention, imitation, and presence of repetitive and stereotyped behavior during the interview with the person and the robot.

Regarding children's attention we found that on average children had more gazes towards the person ($M=11.02$; $SD=6.63$) than towards the robot ($M=8.79$; $SD=5.16$) but this difference was not statistically significant, $T=52$, $p=.454$, $r=.09$ (see Fig. 3, Panel A). However, children's average duration per gaze was significantly lower for the gazes directed at the person ($M=2.73$; $SD=2.74$) than those directed at the robot ($M=6.23$; $SD=6.88$), $T=17$, $p=.046$, $r=.39$ (see Fig. 3, Panel B). Overall, children spent a lower percentage of time looking at the person ($M=41.28$; $SD=26.83$) than at the robot ($M=68.21$; $SD=19.78$), $T=10$, $p=.013$, $r=.49$ (see Fig. 3, Panel C).

Regarding children's imitation of the interview partner's actions, we found that on average children imitated more often the person ($M=3.85$; $SD=0.55$) than the robot ($M=2.93$; $SD=1.83$) but this difference was not statistically significant, $T=3$, $p=.180$, $r=.26$ (see Fig. 3, Panel D).

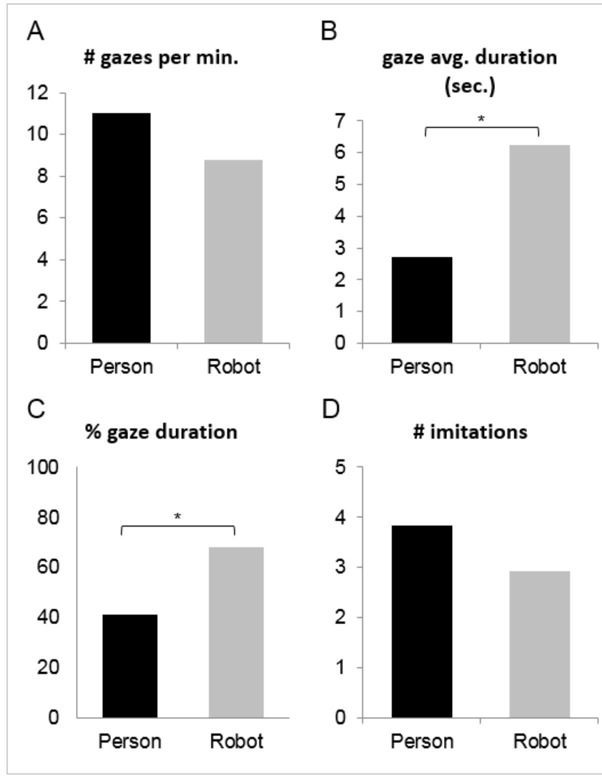

Figure 3: Panel A: number of gazes per minute; Panel B: gaze average duration (in seconds); Panel C: percentage of gaze duration; Panel D: number of imitations. *p<.05

Regarding the presence of repetitive and stereotyped behaviors, we found that children had significantly more chains of repetitive and stereotyped behaviors during the interaction with the person ($M=3.31$; $SD=4.16$) than in the interaction with the robot ($M=1.05$; $SD=1.91$), $T=48$, $p=.037$, $r=.38$ (see Fig. 4, Panel A). Additionally, when children engaged in chains of repetitive and stereotyped behaviors, those were significantly more frequent per minute in the interaction with the person ($M=13.56$; $SD=17.68$) than in the interaction with the robot ($M=4.45$; $SD=9.40$), $T=40$, $p=.0.38$, $r=.39$ (see Fig. 4, Panel B).

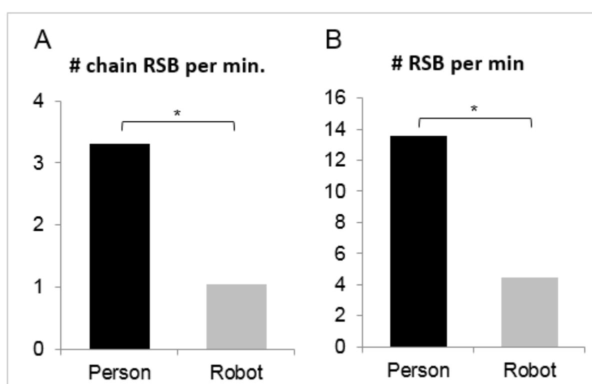

Figure 4: Panel A: number of chains of repetitive and stereotyped behaviors per minute; Panel B: number of repetitive and stereotyped behaviors within chains per minute. *p<.05

4 DISCUSSION and CONCLUSION

The aim of the present study was to assess whether QT robot can be useful in interventions with children with ASD. For that, we compared 15 children with ASD in an interaction with a person and in an interaction with QT robot. We assessed children's gazes towards the interview partner as indications of children's attention, as well as children's imitations, and the presence of repetitive and stereotyped behaviors.

In terms of attention, we found that, even though the differences were not statistically significant, children directed their gaze more often towards the person than towards the robot. However, when they looked at them, they looked significantly longer at the robot than at the person. This indicates that children were diverting their gaze from the person more often than they were from the robot. This can indicate that children were more comfortable looking at the robot than looking at the person. This is observed by the longer periods of time that children spent looking at the robot compared to the person, as well as by the fact, that overall, during the entire interaction, children spent significantly more time looking at the robot than looking at the person. These results are in agreement with the few studies that compared children's attention towards a robot and towards a person and found that children with ASD directed more attention towards the robot [19,20].

In terms of children's imitation of the interview partner, we found that children imitated on average more often the person than the robot but the difference was not statistically significant. Therefore, we can conclude that children with ASD imitate as much QT robot as a person. Our results are therefore not in line neither with those that found that children with ASD imitated more a robot than a person [19,23], nor with those that found that children with ASD imitated more a person than a robot [21].

Finally, an important aspect to evaluate the efficacy of a robot to be used in interventions with children with ASD is the presence of repetitive or stereotyped behaviors during the interaction. Repetitive or stereotyped behaviors can have detrimental effects in children's learning [29] and attention [27] and therefore, fewer of these behaviors could enable more opportunities for the child to engage with the teaching partner and learn. However, this aspect has to date only been assessed in one study with four participants in which they found that children had fewer repetitive or stereotyped behaviors with the robot than with a person [21]. In our study, we found that when children were with the robot they engaged in significantly fewer chains of repetitive or stereotyped behaviors and that when they did, the behaviors were significantly less frequent than with a person.

In summary, the present results demonstrate that QT is an engaging robot that can be beneficial to be used with children with ASD. The fact that children direct more attention towards the robot, imitate the robot as much as a person, and engage in fewer repetitive or stereotyped behaviors with the robot than with a person represent increased learning opportunities for children with ASD. However, the present results can also be due to the brief exposure of children to the robot. It is possible that the robot represents a novelty, which triggers heightened attention and that this effect could disappear over time. Studies with an evaluation of children interaction with the robot after longer periods of interaction are needed to ascertain the long-term benefits of using a robot with children with ASD.

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