Interacting with a Robot for Individuals with ASD

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Individuals with Autism Spectrum Disorder show deficits in communication and social interaction, as well as repetitive behaviors and restricted interests. Interacting with robots could bring benefits to this population, notably by fostering communication and social interaction. Studies even suggest that people with Autism Spectrum Disorder could interact more easily with a robot partner rather than a human partner. The benefits of robots and the reasons put forward to explain these results will be looked at by researchers. The interest regarding robots would mainly be due to three of their characteristics: they can act as motivational tools, and they are simplified agents whose behavior is more predictable than that of a human.

Keywords: autism spectrum disorder ; socially assistive robot ; human–robot interaction ; social skills ; social motivation ; social cognition

1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in communication and social interaction as well as restricted or repetitive patterns of behavior, interests, or activities. A neurobiological dysfunction is thought to be at the root of this disorder. Symptoms appear early in development and have a major impact on the child's daily life in many contexts, particularly in situations of social interaction. Robotics, a currently expanding field, could be of great interest in improving support for specific populations and in particular individuals with ASD. Robots can be categorized according to the different functions they perform. Examples include social robots, which specialize in interacting with humans through gestures and speech, and assistance robots, which aim to help people with special needs. The use of robots has recently expanded into a new field of application: socially assistive robots, which aim specifically to foster engagement in social interactions with specific populations.

According to the DSM-5 classification, the two main criteria for autism are impaired communication and social interaction on the one hand and restricted interests and repetitive behaviors on the other [1]. A review of the literature shows that robots can address both symptoms: their use with autistic people is generally aimed at improving communication skills and reducing repetitive behaviors [2]. Thus, interventions are particularly geared towards communication and social interaction difficulties but also focus on more specific behaviors, such as learning appropriate behaviors and reducing maladaptive behaviors (stereotyped behaviors and anxiety).

To determine the benefits of robots for individuals with ASD, researchers first conducted a search on Google Scholar using the following keywords: "autism + robot + benefits", yielding 24,900 results. As this research is not intended to be systematic, researchers were particularly interested in experimental papers dealing with the progress observed in individuals with ASD following interaction with a robot (see [3] for a systematic review). Researchers have excluded experimental papers dealing with the use of virtual robots, focusing on the use of robots in an interactive setting. In all, researchers selected 50 experimental studies, with publication years ranging from 2008 to 2023.

Three types of interventions can be distinguished according to the objective sought [4]: robots can promote communication and social interaction [5][6][7][8], supporting the learning of specific behaviors, such as emotion recognition [9][10], and reducing the frequency of behaviors deemed maladaptive, including repetitive behaviors and anxiety [11].

2. Fostering Communication and Social Interaction

Social assistance robots have positive effects on the social abilities of children with ASD, who generally show more social behaviors during interaction with a robot than with a human [7][12]. This benefit can be observed across a range of social behaviors impacted by ASD: eye contact, joint attention, collaborative play and activity engagement skills, touch, verbal communication, and imitation. Reseachers will list the effects of a robot for each of these behaviors (see **Table 1** for a summary).

Table 1. Benefits of robots in fostering communication and social interaction in individuals with ASD.

Section	Article	Variable	Effect	Effect p-Value	Robot	Sample Size (ASD)	Mean Age (Standard Deviation)	Functioning/Mean IQ (Standard Deviation)	Duration of Robot Intervention (mn)	Country
Eye contact	Barnes et al. [13]	Eye gaze	robot > human	NA	NAO	3	8.33 (4.04)	NA	1 session (NA)	USA
	Bekele et al. [14]	Eye gaze	robot > human	p<0.05	NAO	6	2.78–4.9 y.o.	NA	1 session (30–50 mn)	USA
	Cao et al. [15]	Eye gaze	robot > human	p<0.05	NAO	15	4.96 (1.10)	NA	1 session (NA)	China
	Costa et al. [16]	Eye contact	robot > human	p<0.001	KASPAR	8	6–10 y.o.	NA	7 sessions (NA)	UK
	Costa et al. [17]	Eye gaze	robot > human	p<0.05	QTRobot	15	9.73 (3.38)	IQ < 80 (n = 8); 80–120 (n = 6); IQ > 120 (n = 1)	1 session (1.5–4.3 mn)	Luxembourg
	Damm et al. [18]	Eye gaze	robot > human	p<0.05	FLOBI	9	21 (NA)	112.5 (range: 94–133)	NA	Germany
	David et al. [19]	Eye contact	robot > human for 2/5 children	p=0.01	NAO	5	3–5 y.o.	LF-HF	8–12 sessions (10 mn/session, 1/day)	Romania
	Duquette et al. [20]	Eye contact	robot > human	β=0.35	TITO	4	5.1 (NA)	LF	3/week for 7 weeks (NA)	Canada
	Scassellati et al. [8]	Eye contact with other people	pretest < post-test	p<0.01; p<0.05	JIBO	12	9.02 (1.41)	IQ ≥ 70	23 sessions (30 mn/session, 1/day)	USA
	Shamsuddin et al. [21]	Eye contact	robot > human	NA	NAO	1	10 y.o.	107	1 session (15 mn/session)	Malaysia
	Simlesa et al. [7]	Eye contact	robot > human	p<0.05	NAO	12	5.2 (0.63)	MA: 2–3 y.o.	1 session (NA)	Croatia
	Simut et al. [22]	Eye contact	robot > human	p<0.05	PROBO	30	6.67 (0.92)	91.23 (range: 70–119)	1 session (15 mn/session)	Belgium
	Tapus et al. [23]	Eye gaze	robot > human	p<0.05	NAO	4	4.2 (1.67)	NA	7–13 sessions (8 mn/session, 2/day)	Romania
	Wainer et al. [24]	Eye contact	robot > human	p<0.05	KASPAR	6	6–8 y.o.	NA	2 sessions (15 mn/session)	UK
Joint attention	Anzalone et al. [25]	Joint attention	robot < human	p<0.01	NAO	16	9.25 (1.87)	73 (14)	1 session (NA)	France
	Cao et al. [15]	Joint attention	robot = human	p>0.05	NAO	15	4.96 (1.10)	NA	1 session (NA)	China
	Cao et al. [26]	Joint attention	robot < human	p<0.001	NAO	27	46.37 months (4.36)	MA: 42 months max	2 session (NA)	The Netherlands
	Ghiglino et al. [6]	Joint attention	robot = human	p>0.05	Cozmo	24	5.79 (1.02)	58.08 (19.39)	5 weeks (10 mn/session)	Italy
	Kajopoulos et al. [27]	Joint attention	pretest < post-test	p<0.05	CuDDler	7	4–5 y.o.	NA	6 sessions over 3 weeks (20 mn/session)	Singapore

Section	Article	Variable	Effect	Effect *p*-Value	Robot	Sample Size (ASD)	Mean Age (Standard Deviation)	Functioning/Mean IQ (Standard Deviation)	Duration of Robot Intervention (mn)	Country
Interaction	Kumazaki et al. [28]	Joint attention	time +; robot > human	$p<0.01$	CommU	28	70.56 months (6.09) (robot group); 69.00 (4.39) (control)	NA	1 session (15 mn)	Japan
	So et al. [29]	Joint attention	pretest < post-test (robot)	$p<0.05$	HUMANE	38	7.51 (0.87) (robot group); 7.91 (0.89) (human group)	LF	6 sessions (30 mn/session)	China
	Taheri et al. [30]	Joint attention	time +	$p<0.05$	NAO/ALICE-R50	6	6–15 y.o.	LF-HF	12 sessions over 3 months (30 mn/session)	Iran
	Warren et al. [31]	Joint attention	time +	$p<0.01$	NAO	6	3.46 (0.73)	NA	4 sessions over 2 weeks (NA)	USA
	Wiese et al. [32]	Gaze cueing effect	robot > human	$p<0.01$	EDDIE	18	19.67 (1.5)	NA	1 session (15 mn)	Germany
	Ghiglino et al. [6]	Social interaction initiation	robot > human	$p<0.05$	Cozmo	24	5.79 (1.02)	58.08 (19.39)	5 weeks (10 mn/session)	Italy
	Kim et al. [33]	Social behaviors towards peer	robot > human	$p<0.05$	PLEO	24	4–12 y.o.	NA	NA	USA
	Pop et al. [34]	Collaborative game	robot > human	$p<0.05$	PROBO	11	4–7 y.o.	IQ >70	8 sessions (1 mn/session)	Romania
	Pliasa et al. [35]	Social interaction initiation	robot > human	$p<0.05$	DAISY	6	6–9 y.o.	NA	2 sessions (20 mn/session)	Bulgaria
	Rakhymbayeva et al. [36]	Engagement time	tendency time 2 > time 1; familiar > unfamiliar activities	$p=0.05$; $p<0.05$	NAO	7	6.1 (2.7)	LF	7–10 sessions (15 mn/session)	Khazakstan
	Stanton et al. [37]	Social interaction initiation	robot > human	$p<0.05$	AIBO	11	5–8 y.o.	NA	1 session (30 mn)	USA
	Wainer et al. [24]	Cooperation in game	robot > human	$p<0.01$	KASPAR	6	6–8 y.o.	NA	2 sessions (15 mn/session)	UK
Touch	Costa et al. [16]	Spontaneous touch	robot > human	NA	KASPAR	8	6–10 y.o.	NA	7 sessions (NA)	UK
	Simlesa et al. [7]	Touch	robot > human	$p<0.05$	NAO	12	5.2 (0.63)	MA: 2–3 y.o.	1 session (NA)	Croatia
Communication	Farhan et al. [38]	Verbal and non-verbal communication	time 4 > time 1	NA	NAO	4	5, 12, 13, 24 y.o.	range: 41–47	4 sessions (NA)	Bangladesh
	Huskens et al. [5]	Self initiated questions	pretest < post-test; robot = human	$p<0.05$; $p>0.05$	NAO	6	3-14 y.o.	IQ >80	4 sessions (10 mn/session)	Netherlands

3. Fostering Specific Behaviors

Section	Article	Variable	Effect	Effect p-Value	Robot	Sample Size (ASD)	Mean Age (Standard Deviation)	Functioning/Mean IQ (Standard Deviation)	Duration of Robot Intervention (mn)	Country
	Kim et al. [38]	Speech	robot > human	p<0.05	PLEO	24	4–12 y.o.	NA	NA	USA
	Kumazaki et al. [39]	Posture, gaze, facial expressions	robot > human	p<0.001	ACTROID-F	29	29.1 (2.6)	IQ ≥ 70	1 session (25 mn)	Japan
	Simlesa et al. [7]	Vocalization	robot < human	p<0.01	NAO	12	5.2 (0.63)	MA: 2–3 y.o.	1 session (NA)	Croatia
	Stanton et al. [37]	Speech	robot > human	p<0.05	AIBO	11	5–8 y.o.	NA	1 session (30 mn)	USA
	Syrdal et al. [40]	Communication	number of interactions +	p<0.05	KASPAR	19	2–6 y.o.	NA	NA	UK
	Taheri et al. [30]	Verbal communication	time +	p<0.05	NAO/ALICE-R50	6	6–15 y.o.	LF-HF	12 sessions over 3 months (30 mn/session)	Iran
Imitation	Conti et al. [41]	Imitation	time +	NA	NAO	6	5 and 10 y.o.	LF	15 sessions (6–8 mn/session)	Italy
	Costa et al. [17]	Imitation	robot = human	p>0.05	QTRobot	15	9.73 (3.38)	IQ < 80 (n = 8); 80–120 (n = 6); IQ > 120 (n = 1)	1 session (1.5–4.3 mn)	Luxembourg
	Duquette et al. [20]	Imitation of facial expressions, of words and gestures	robot > human; robot < human	NA	TITO	4	5.1 (NA)	LF	3/week for 7 weeks (NA)	Canada
	Pierno et al. [42]	Imitation velocity	robot > human	p<0.001	ROBOTIC ARM	12	11.1 (NA)	HF	1 session (NA)	Italy
	Simlesa et al. [7]	Imitation	robot = human	p>0.05	NAO	12	5.2 (0.63)	MA: 2–3 y.o.	1 session (NA)	Croatia
	Soares et al. [43]	Imitation of emotions	post-test > pretest (robot), post-test = pretest (human)	p<0.05; p<0.05; p>0.05	Zeno	45	6.8 (1.5) (robot group); 7.5 (1.4) (human group); 7.8 (1.2) (control)	HF	2/week for 3 weeks (5–15 mn/session)	Portugal
	Taheri et al. [44]	Imitation	robot < human	p<0.001	NAO	20	4.95 (2.01)	NA	1 session (NA)	Iran
	Zheng et al. [45]	Imitation quality	robot > human	p<0.05	NAO	6	3.83 (0.54)	NA	2 sessions (NA)	USA

The application of social robots with autistic individuals can also target the improvement of a particular behavior. The work presented in this section is of two types. Some studies promote the emergence of relevant and appropriate behaviors, while others aim to reduce maladaptive behaviors (stereotyped or repetitive behaviors) and anxiety. Researchers will examine the benefits of a robot on these behaviors (see **Table 2** for a summary).

Table 2. Benefits of robots in fostering specific behaviors in individuals with ASD.

Section	Article	Variable	Effect	Effect p-Value	Robot	Sample Size (ASD)	Mean Age (Standard Deviation)	Functioning/Mean IQ (Standard Deviation)	Duration of Robot Intervention (mn)	Country
Appropriate behaviors	Bharatharaj et al. [46]	Touching interaction	NA	NA	KiliRo	24	9.71 (3.24)	NA	1/day for 7 weeks (60 mn/session)	India
	Costa et al. [16]	Appropriate touch	gentle touch > harsh	p<0.05	KASPAR	8	6–10 y.o.	NA	7 sessions (NA)	UK
	David et al. [19]	Turn-taking skills	robot = human for 3 children	p>0.05	NAO	5	3–5 y.o.	LF-HF	8–12 sessions (10 mn/session, 1/day)	Romania
	Ghiglino et al. [47]	Theory of Mind skills	training with humanoid robot > non-anthropomorphic robot and traditional therapy	p<0.001; p<0.01	iCub, COZMO	43	5.8 (1.14)	71.48 (16.50) (COZMO); 71.14 (15.49) (iCub)	2/week for 8 weeks (15 mn/session)	Italy
	Holeva et al. [48]	Theory of Mind skills (NEPSY II)	robot training = human; pretest < post-test	p>0.05; p<0.001	NAO	44	9.48 (1.95)	IQ > 70	2/week for 3 months (NA)	Greece
	Lakatos et al. [49]	Visual Perspective Taking and Theory of Mind skills (Charlie test)	pretest < post-test	p<0.05	KASPAR	13	8.11 (1.96)	79.30 (14.33); range: 60–103	1 to 10 sessions (15–20 mn/session)	UK
	Lee et al. [50]	Proper force of touching	feedback > no feedback	p<0.05	Touch pad	1	22 y.o.	49	1 session (NA)	Japan
	Marino et al. [10]	Recognition and understanding of emotions	pretest < post-test (robot training); pretest = post-test (human training)	p=0.001; p>0.05	NAO	14	73.3 months (16.1) (robot group); 82.1 (12.4) (human)	NA	10 sessions (90 mn/session, 2/week)	Italy
	So et al. [51]	Recognition and production of intransitive gestures	robot training > no training	p<0.05	NAO	30	5.10 (0.83) (experimental group); 5.8 (0.35) (control)	NA	4 sessions (30 mn/session, 2/week)	China
	So et al. [9]	Recognition and production of emotional gestures	robot training > no training	p<0.001	NAO	13	8.99 (2.14) (experimental group); 9.50 (2.42) (control)	range: 49–67	4 sessions (30 mn/session, 2/week)	China
	So et al. [52]	Recognition and production of intransitive gestures	robot training = human	p>0.05	NAO	23	9.17 (1.29) (robot group); 8.92 (0.93) (human)	range: 46–74	5 sessions (30 mn/session, 2/week)	China

HF: High-Functioning Autism; IQ: Intellectual Quotient; LF: Low-Functioning Autism; MA: Mental Age; NA: Not Available; y.o.: Years Old.

Section	Article	Variable	Effect	Effect *p*-Value	Robot	Sample Size (ASD)	Mean Age (Standard Deviation)	Functioning/Mean IQ (Standard Deviation)	Duration of Robot Intervention (mn)	Country
	Takata et al. [53]	Understanding of others' feelings and behaviors	pretest < post-test	$p<0.01$	Sota, CommU, A-Lab android ST	14	17.57 (3.39)	89.50 (10.95)	5 sessions (1 h/session, 1/day)	Japan
	Wood et al. [54]	Theory of Mind skills (Charlie test)	pretest < post-test for 7/12 children	$p<0.05$	KASPAR	12	11–14 y.o.	MA: 6–14 y.o.	2–10 sessions (NA)	UK
Reducing maladaptive behaviors	Bharatharaj et al. [46]	Stress level	pretest > post-test	$p<0.05$	KiliRo	24	9.71 (3.24)	NA	1/day for 7 weeks (60 mn/session)	India
	Costa et al. [17]	Stereotyped behaviors	robot < human	$p<0.05$	QTRobot	15	9.73 (3.38)	IQ < 80 (*n* = 8); 80–120 (*n* = 6); IQ > 120 (*n* = 1)	1 session (1.5–4.3 mn)	Luxembourg
	Kumazaki et al. [39]	Stress level	robot < human	$p<0.01$	ACTROID-F	29	29.1 (2.6)	IQ ≥ 70	1 session (25 mn)	Japan
	Pop et al. [34]	Stereotyped behaviors	robot < human	$p<0.05$	PROBO	11	4–7 y.o.	IQ > 70	8 sessions (? mn/session)	Romania
	Shamsuddin et al. [21]	Stereotyped behaviors	robot < human	NA	NAO	1	10 y.o.	IQ = 107	1 session (15 mn)	Malaysia
	Shamsuddin et al. [11]	Stereotyped behaviors	robot < human	NA	NAO	6	8.9 (NA)	range: 46–78	5 sessions (15 mn/session)	Malaysia
	Stanton et al. [37]	Stereotyped behaviors	robot < toy	$p=0.06$	AIBO	11	5–8 y.o.	NA	1 session (30 mn)	USA

HFA: High-Functioning Autism; IQ: Intellectual Quotient; LF: Low-Functioning Autism; MA: Mental Age; NA: Not Available; y.o.: Years Old.

3.1. Supporting the Learning of Appropriate Behaviors

Interactions with robots offer the possibility of designing specific remediation to support particular learning, such as learning turn-taking [19][55] or non-verbal language gestures [9][51], emotion recognition [10], or regulating touch and physical contact [16].

In addition to using robots to increase the occurrence of certain behaviors, other protocols use robots to reduce the occurrence of maladaptive behaviors.

3.2. Reducing Maladaptive Behaviors: Repetitive Behaviors and Anxiety

The use of the NAO robot could reduce the percentage of stereotyped behaviors in children aged 5 to 13 [11][21]. In other studies, children also show fewer stereotyped behaviors when performing an activity with a robot partner than with a human partner [17][34]. The frequency of autistic behavior tended to decrease when children interacted with an AIBO dog robot rather than a mechanical dog toy [37]. In addition, using a KILIRO parrot robot for 60 min a week for 7 weeks helps both children and adolescents (aged 6–16) to reduce their stress levels [46]. In adults with ASD, the stress reduction observed during job interview training was greater for training with an android robot than with a human [39], suggesting that interacting with a robot is less stressful than interacting with a human for individuals with ASD. It is worth noting that the most anxious children display more stereotyped behaviors [56]. Stress levels could be linked to the occurrence of global and motor stereotyped behaviors (but not to verbal stereotyped behaviors) [57]. Reducing the stress involved in interacting with a human by using a robot as a partner could therefore help to reduce stereotyped behaviors in individuals with ASD.

In this way, socially assistive robots can promote communication and social interaction in autistic children, support specific social learning, and reduce repetitive behaviors. However, the results are mixed when researchers compare the effectiveness of training with a robot with that of training with a human. While some studies show that robots are more effective than humans (e.g., [6][7][13][19][45][47]), others show that they are comparable (e.g., [5][17][48]) or even less effective [25][26] than humans. This heterogeneity in results can be partly explained by the wide variety of skills targeted by robot intervention. A meta-analysis confirms the benefits of robots on the social development of children with ASD, but not on motor or emotional aspects [3].

4. A Preference for Interacting with Robots Rather than Humans in Individuals with Autism Spectrum Disorder?

The benefits for individuals with ASD of interacting with a robot (at least in terms of social development) raise several questions. First, it is worth asking whether this type of interaction is more attractive to individuals with ASD than interaction with a human, as has been proposed in several studies [7][47][58][59]. In the next section, researchers will look at how individuals with ASD perceive robots, and what characteristics they attribute to them.

5. Reasons Provided to Explain the Benefits of Robots

Several explanations can be proposed based on different theories aimed at explaining the social difficulties observed in autism. Researchers have already observed that people with ASD have social difficulties and show less interest in social stimuli than Typically Developing (TD) individuals. The link between social skills and social motivation seems well established in children with ASD: those with the least social motivation have more severe social difficulties [60][61][62]. Nevertheless, the meaning of this association remains to be determined.

Two main theories have been proposed to explain the association between social difficulties and reduced social interest observed in autism [63]: Social Motivation Theory [64] and Social Cognition Theory [65][66]. Researchers will analyze the two theories that seek to explain the causality between these two characteristics of ASD and build on these theories to explain the benefits brought about by robots.

6. Conclusions

In conclusion, the use of robots with people with ASD appears to be beneficial in encouraging communication and social interaction, supporting the learning of specific social behaviors, and reducing maladaptive behaviors. Interaction with robots could improve the social skills of individuals with ASD [3]. Children with autism touch and look more at a robot than at a human [7][17][19]. They also show a greater tendency to follow a robot's gaze than a human's gaze [32]. Children's participation in an activity is increased when a robot is present [34][36], thus increasing interaction initiation [6][35] and speech production [33]. During an action imitation task performed by a human or robotic arm, children with autism perform better with the robotic arm, while TD children perform better with the human arm [42]. Furthermore, when ToM training is implemented, children with ASD make more progress with a humanoid robot than with a human [47], and the same results are observable in emotion recognition training with an iconic robot [10]. Finally, studies suggest that the stress felt by individuals with ASD during social interactions could be reduced with a robotic partner [39], leading to a decrease in the occurrence of stereotyped behaviors [17][34]. Further studies are needed to confirm the influence of robots on stereotyped behavior, but the benefits of robots on social development have been confirmed by a recent meta-analysis [3].

Although autistic children may categorize robots in the same way as TD children, they seem more attracted to robots and attribute more human characteristics to them. Some studies even suggest that theyare more interested in robots than in humans. Researchers sought to explain the benefits of robots by drawing on two theories: Social Motivation Theory and Social Cognition Theory. On the one hand, considering Social Motivation Theory, individuals with ASD may show more interest in a non-human agent than in a human one. This increased interest in interaction would then allow them to accumulate social experience, which could consequently reduce their social difficulties. On the other hand, as Social Cognition Theory argues that people with ASD engage less in interactions due to difficulties in understanding the social world, it is conceivable that a simpler, more predictable agent such as a robot could reduce these difficulties. As a result, this type of agent would encourage autistic individuals to engage more fully in social interactions. The robot, as a more attractive, simplified, and predictable social agent than a human, would thus encourage social interactions in autistic individuals. For children with significant social difficulties, robot-assisted training could thus constitute a step of intermediate difficulty compared to training with a human [67].

It therefore seems appropriate to rely on this type of agent when assessing the social skills of individuals with ASD: by reducing the difficulty of the interaction, a robot could enable children to better mobilize their abilities, leading to better estimation of their social skills. This suggests that psychology tests might be more successful if the experimenter is a robot rather than a human, as has already been shown in TD children [68][69][70][71][72]. The robot would then provide a more accurate means of assessing social–cognitive functioning [73][74], which would be particularly relevant for children with ASD [75].

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