The Effectiveness of Robot-Assisted Interventions for Children with Autism Spectrum Disorder: A Literature Review

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The Effectiveness of Robot-Assisted Interventions for Children with Autism Spectrum Disorder: A Literature Review

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Abstract: *The increase in global prevalence of autism spectrum disorder (ASD) children not only leaves the stakeholders in concern, but also the healthcare systems as it indicates that more patients will be in need of long-term support. Previous studies have proved that early intervention can improve the symptoms of ASD, allowing the children to be more independent in their daily living activities. Advancement in technology has allowed robotics to be implemented as a socially assistive robot (SAR) tool for early intervention of ASD children . This paper aims to review the current robots that were being used in intervention for ASD children and its effectiveness in tackling the deficits of skills in ASD children. As results, most robots included in this review has significantly improved the engagement of children during the intervention session. However, certain limitations are noted across the studies. Therefore, this review highlights the potential and limitation of current robot-assisted intervention for improvement in providing support for ASD children.*

Keywords: autism children; robot-assisted; interventions; effectiveness

1. INTRODUCTION

Autism spectrum disorder (ASD) is known as a neurodevelopmental disorder that is characterized by the deficits in social communication and interaction across multiple contexts, including social-emotional reciprocity, nonverbal communicative behavior, and understanding of relationships [1]. It is also presented with the restricted and repetitive behavior, interest or activities including repetitive motor movements, inflexible adherence to routines, abnormal and high fixated interest and hyper- or hypo-reactivity to sensory input [1]. These symptoms of ASD have significantly impaired the individual's social and occupational involvement [2][3], as well as other functional areas. It is normally accompanied with other neurodevelopmental disorder like intellectual disability and neurodevelopmental motor disorders.

ASD has affected an approximate 1 out of 100 children globally [4], and this increase in prevalence of ASD children is concerning as it is not only affect the individuals, but also significantly affects the family, caregivers and healthcare systems. A study showed that ASD has impacted the family in many aspects including their mental health [5][6] and economic costs such as healthcare services, therapeutic and special education costs [7]. Apart from that, ASD has also impacted the socioeconomic of a country due to lost of workforce participation, taxation payment to federal government and welfare payment [8], and this is expected to increase by 2030, which calls for a crucial early intervention for ASD children. Previous studies have mentioned the significance of early intervention for ASD children [9][10][11][12]. A meta-analysis of efficacy of early interventions for ASD children [9] reported positive outcomes in cognitive ability, daily living skills and motor skills while a study [10] highlights a significant reduction in autistic symptoms due to early intervention. Many previous researches had discussed on early interventions approaches that is effective in improving the children developmental outcomes. For example, a meta-analysis by Yu et al., (2020) [13] suggested applied behavior analysis (ABA) based intervention for early intervention in the area of socialization, communication and expressive language while Franz et al., (2022) [14] found that naturalistic developmental behavioral intervention, and developmental and behavioral interventions approaches such as Early Start Denver Model (ESDM) [15] improved child developmental outcomes. However, children with ASD may be struggling in attaining their focus throughout the session as they deal with challenges in social domains. Hence, the outcomes of the intervention may not be optimized.

The advancement in technology nowadays has allowed vast technology such as robotic and AI driven system to be implemented in many sectors [34] including intervention for ASD children. This kind of technology has made it possible to better incorporate the children throughout the session. This paper will review previous studies on the current robot being used in intervention for ASD children and what skills are mostly targeted while using the robot during intervention session. This paper will also review on how the effectiveness of robot-assisted intervention can be evaluated through different methodology.

2. METHODOLOGY

A literature search was performed using four databases: ProQuest, Scopus, ScienceDirect and SpringerLink. The search was limited to relevant research articles published between 2020 until 2026, using the

combinations of keywords such as “robot-assisted”, “training”, “intervention” and “autism spectrum disorder children”. The inclusion criteria were: (1) studies focused on children with ASD; (2) interventions involving assistive robots; (3) studies involving the evaluation of effectiveness of robot-assisted intervention. Articles were excluded if they were review papers, conference abstracts without full text or not available in English.

3. FINDINGS

This paper will review on the current robot-assisted training or intervention that has been done by previous researches before, including the application of robot in the intervention session and how it addresses the deficit of skills in ASD children.

3.1 Type of robot used in intervention fro ASD children

Previous researches have implemented the use of robotic technology in the rehabilitation setting for ASD children with the intention to improve their engagement during the therapy session. Different robots have been used as a socially assistive robot (SAR) tool in enhancing the deficit in different skills of ASD children. Relevance studies between 2020 until 2026 have been identified. One of the most commonly used robots is NAO. NAO is an autonomous and programmable humanoid robot that has been widely used for research, educational and entertainment purposes [16]. The programming capability of the robot has made it a popular choice in the research area of robotics application in therapy for ASD children. It is a small, child-sized humanoid robot and equipped with unique components and features such as camera, sensors and integrated recognition system. Almost half of the studies reviewed in this paper utilized NAO as SAR in the proposed robot-assisted intervention. For example, a study by [17] used NAO for investigating the possibility of combining the robot with their mobile application, in order to enhance the educational experience of the ASD children. Study by [18] also used the robot model NAO H-21 in his study to look at the imitation skills performance of the ASD children compared to the typically developing children. The other studies also used different models of NAO in their studies related to ASD children [19,20,21,22]. Table 1 summarizes the application of different NAO models in robot-assisted intervention for ASD children.

Table 1. Application of NAO robot

Studies	Model of NAO	Description of use
[17]	Not specified	Conduct lessons; Interact with ASD children; Facial recognition
[18]	NAO H-21	Perform pre-set body gesture imitation actions; Platform for studying the children’s response and imitation skills
[19]	Not specified	Give instruction; Rewarding and empowering child; Collect real-time data for action, gestures and speech recognition
[20]	Not specified	Perform activities (social and emotional skills) including tasks on joint attention, imitation, turn-taking and emotion recognition
[21]	NAO6	Provide pre-programmed scenarios of social interaction; Camera is used to record the child-robot interaction
[22]	Not specified	Provide stimulus, prompts and reinforcement in the form of game scenarios according to Pivotal Response Treatment elements

Apart from NAO, previous researchers also used MARIA T21 in the implementation of robotic technology in the intervention for ASD children. MARIA T21, a term for Mobile Autonomous Robot for Interaction with Autistics and Trisomy 21, is a socially assistive robot specifically targeted for children with ASD and Down syndrome. It is a child-sized robot equipped with an RGB camera and a 10-inch screen for expressing emotions. It is also equipped with other features such as speakers, projectors, laser sensor and wheels for mobility. In studies by [23, 24] and [25], MARIA T21 was used by integrating the developed serious games targeted for different element of social and motor skills. In those studies, the developed games were projected to the floor by using the MARIA T21, allowing a more interactive learning session for ASD children.

Another type of robot that is commonly used by previous researchers is Cozmo. Cozmo is a small, non-humanoid robot that is designed intentionally to provide an interactive learning experience for children. It has features such as LCD screen, sensor, camera and wheels that make it ideal as an engaging companion for educational purposes. Studies by [26, 27] and [28] have implemented the use of Cozmo as an assistive tool to provide cues in joint attention and social skills training for ASD children. In the same study [27], Ghiglino et al.(2023) also used iCub, a humanoid robot in training the social cognition in ASD children.

[29] has proposed different appearances of a newly developed robot, known as CASTOR, a compliant, soft robot, that acts as a social mediator and facilitator in training related ASD skills (verbal communication and emotions expressions), to investigate the influence of different appearance of robot in the engagement of ASD children during the therapy session. Next, the ability of interacting through bodily expressions of Kaspar, a realistic, human-like features robot that equipped with

touch sensor, has allowed [30] to implement the use of the robot in his study to enrich a human-robot interaction between the ASD children and the robot. Another robot that has been implemented for ASD children was mentioned by [31]. In the study, Bettencourt et al. (2025), has used QTRobot, a specifically designed humanoid robot for ASD and special needs children, to qualitatively explore the feasibility and effect of the developed interface in the engagement of ASD children in robot-assisted intervention sessions. Table 2 summarizes the different types of robot (other than NAO) being used in intervention for ASD children.

Table 2. Other robots used in intervention for ASD

Studies	Robot	Description of use
[23][24] [25]	MARIA T21	Integrated with the developed serious games to be projected on the floor during the session
[26][27] [28]	Cozmo	Provide cues for joint attention and social skills intervention
[29]	CASTOR	Performs different emotions to be imitated by the ASD children
[30]	Kaspar	Perform the pre-programmed movements and speech triggered by the touch; Provide appropriate feedback and expressions
[31]	QTRobot	Interact with ASD children by giving them praises and encouraging words
[27]	iCub	Provide cues for joint attention and social skills intervention

3.2 Evaluation of different skills in ASD children

Deficits in social skills are the significant issue that distinguish the ASD children from the typically developed children [1] . Therefore, primarily, robots have been used as a tool to socially engage the ASD children during the intervention session. Although the robots have been mostly used as social facilitators, researchers also used the robot to improve the deficits in other specific skills related to ASD children. Table 3 summarized the skills evaluated in the robot-assisted intervention studies.

Table 3. Skills evaluated in different studies

Skills evaluated	Studies
Engagement	[17] - [31]
Social skills	[17] - [31]
Joint attention	[17][25][29][19][30][31] [21][22][20][26]
Emotion recognition	[25][[29][19][30][31][21][22][20]
Imitation	[18][28][23][25][19][30] [21][22][20][26]
Motor skills	[24]

All studies reviewed in this paper evaluated different set of skills in the social domain. The element of social domain of ASD children during the robot-assisted intervention session was measured by using different approaches. Most of the studies utilized standardized assessment tools to evaluate the performance of skills in the social domain. Chevalier et al. (2022) and Ghiglino et al. (2021) used Early Social Communciation Scales (ESCS) to assess the social skills (joint attention, social interaction & behavioral requests) while Holeva et al. (2024) used Developmental Neuropsychological Assessment Second Edition (NEPSY-II) to evaluate the set of skills (conversation, emotional self-regulation & problem-solving skills) in the social domain of the ASD children. Bettencourt et al. (2025) used Autism Diagnostic Observation Schedule Second Edition (ADOS-2) to measure the skills of imitation, turn-taking and musical reciprocity and joint attention in social domain. In his study, Van Den Berk-Smeekens et al. (2022) evaluated the communicative skills of ASD children by using a scoring tool known as Social Responsiveness Scale (SRS). Apart from assessment tools, the social skills of ASD children were also evaluated by methods like AI-driven detection system and recording of duration or frequency of certain parameters. For example, Al-Nafjan et al. (2023) and Pinto-Bernal et al. (2023) utilized detection model for facial, eye-gaze and movement recognition while measuring the engagement of ASD children during the robot-assisted intervention session. Studies by Freitas et al. (2024), Telisheva et al. (2022) and Mutawa et al. (2023) recorded the duration or frequency of certain parameters (e.g. number of eye contact, duration of eye-gaze and engagement) to measure the engagement of ASD children during the session.

Apart from skills in social domain, other skills such as motor skills were also measured using different methods. For example, Campos et al. (2021) used an established scoring tools known as Goal Attainemnt Scale (GAS) to evaluate the social interaction and motor skills (propriocepton, motor coordination, balance) while Telisheva et al. (2022) and Taheri et al. (2021) used Likert Scale to measure the element of motor skills of ASD children. In his study, Da Luz Schreider et al. (2024) used Psychomotor Battery by Fonseca [24] to measure the element of postural balance, proprioception and motor coordination in the motor skills. Table 4 summarizes the different methods employed for measuring the outcomes of the studies.

Table 4. Different methods for measuring the outcomes

Method	Tools/Description	Studies
Assessment scoring tools	ESCS	[26][28]
	NEPSY-II	[19]
	GAS	[23]

	ADOS-2	[31]
	SRS	[22]
	Likert Scale	[18][20]
	Psychomotor Battery	[24]
AI detection model	Facial, eye-gaze, movement recognition	[21][29]
Duration/Frequency record	Engagement time, eye-gaze time, number of eye contact	[17][20][25]

(Abbreviation: ESCS = Early social communication scales; NEPSY-II = Developmental Neuropsychological Assessment 2nd. Edition; GAS = Goal Attainment Scaling (GAS); ADOS-2 = Autism Diagnostic Observation Schedule 2nd. Edition; SRS = Social Responsiveness Scale)

3.3 Effectiveness of robot-assisted intervention

The effectiveness of the use of robot-assisted intervention can be evaluated through any noticeable improvement in skills of ASD children. All studies reviewed in this paper employed different research design such as quasi-experimental [18], comparative [17], cross-over study [28], pilot study [25,29], mixed-method of qualitative and quantitative study [23], randomized controlled trial (RCT) [19,22], exploratory study [31,21,24] and pre-post study [30]. The number of participants across these multiple studies ranged from 6 to 73 children, comprises of both ASD and typically developing children with range of age from 3 to 15 years old.

Similar findings can be found in [17,25,30,20] where children with ASD have better engagement during the robot-assisted intervention sessions while Ghiglino et al. (2021) [28], Bettencourt et al. (2025) [31], Da luz et al. (2024) [24] and Holeva et al. (2024) [19] reported the improvement in social initiation and interaction skills due to the robot-assisted intervention. [25] and [23] also have similar findings where high motivation and curiosity during robot-assisted intervention sessions were observed among children. Other than engaging ASD children during the session, it was also found across different studies that robots can be functional tools for developing specific skills. For example, improved emotion recognition skills can be found in studies [29][19] where ASD children are able to recognize basic emotions (e.g. happiness and sadness). It was also found in studies where better performance in behavioral request and imitation skills were observed [28,30,31]. Other than that, Freitas et al. (2024) [25], Telisheva et al. (2022) [20] and Mutawa et al. (2023) [17] noted improvements in attention and focus element of social skills, especially when the difficulty of the intervention was adjusted to the child's performance during the intervention session.

Although robot-assisted intervention for ASD children exhibited positive outcomes across most of the studies, Taheri et al. (2021) [18] reported that imitation skills are better in teacher-child mode compared to robot-child mode. A varied result were reported from Pinto-Bernal et al. (2023) [29] as they found that robots did not perform better than therapists in teaching emotion recognition but still, they attain more children's attention during the session compared to the therapists only-based intervention. Although study by Ghiglino et al. (2021) [28] shows improvement in social domains, he also noted that there is no significant improvement in joint attention skills during the robot-assisted intervention. For joint attention skills evaluation in [30] and [31], there are unclear results noted as some children show improvement but some did not.

Other than evaluation of targeted skills of ASD children, some studies also evaluate the perception by stakeholders of ASD children [19][30][29]. This was done through different approaches such as questionnaires (completed by stakeholders), interviews and scoring methods using standardized scales. Holeva et al. (2024) [19], Zorcec et al. (2021) [30] and Pinto-Bernal et al. (2023) [29] reported positive perception by parents and clinician, in satisfaction towards the robot-assisted intervention. This is due to the better participation and reduction of anxiety among the children during the sessions. Apart from that, the appearance of the robot was also emphasized by Pinto-Bernal et al. (2023) and Campos et al. (2021) as this will affect the children's behavior towards the intervention session [29][23]. Table 5 summarizes the effectiveness of robot-assisted intervention in improving deficits of skills of ASD children across different studies.

Table 5. Effectiveness of robot-assisted intervention

Studies	Engagement	Social Skills	Human vs. robot
[18]	√	√	Human > robot
[17]	√	√	-
[28]	√	√	-
[23]	√	√	-
[25]	√	√	-
[29]	√	√	Human > robot
[19]	√	√	Human = robot
[30]	√	√	-
[31]	√	√	-
[21]	√	√	-
[22]	√	√	Robot >Human
[24]	√	√	-
[20]	√	√	-
[26]	√	√	Robot > Control

4. DISCUSSION

Most of the reviewed studies reported enhancement in engagement of ASD children towards the robot-assisted intervention session. In addition, the use of robots in intervention for ASD children also increased performance in other specific developmental skills such as emotion recognition skills [19,29], imitation skills[28][30], behavioral requests skills [31] and motor

skills [24]. The improvement in engagement during the intervention session was due to the characteristics of robots. Unlike humans, robots' actions are predictable and consistent [32]. The unpredictable behavior of humans will most probably cause anxiety to ASD children. Hence, the predictability behavior of the robot reduces anxiety experienced by the ASD children. In addition, the characteristics of robots that are less expressive also contribute to high engagement and increase in social interaction skills of ASD children. ASD children can be visually sensitive towards emotions expressed by humans. Therefore, having a less expressive creature as a companion during the intervention allows the children to feel safe and eventually results in better performance of social interaction skills.

The findings from a study [29] found that therapists outperform robots in teaching children emotion recognition. This result may indicate that interaction may be better in providing cues during the intervention session. This aspect of interaction can be taken into account while developing robots specific for ASD children. Other than that, some studies also show no significant improvement in skills like joint attention [28]. This may be due to the smaller number of samples used in the study.

5. LIMITATIONS AND FUTURE WORKS

Most of the reviewed studies involved small sample size that may limit the generality of the study. Hence, not all findings from these studies are applicable to the population of ASD children. In addition, only two out of the studies involved RCT experimental design [19][22]. RCTs are mostly known to be the gold standard in evaluating a new intervention or treatment in scientific study as it can reduce bias and be able to investigate the cause and effect relationship in the study. Furthermore, some studies [23] are affected due to the effect of COVID-19 [33] which may cause disruption in the data collection procedure of the study. Apart from that, most of the reviewed studies did not have follow-up protocol, and this may also limit the long-term positive outcomes on skills of ASD children. Therefore, future research is expected to address these limitations in the sample size, duration of study, as well as the experimental design in evaluating the effectiveness of the robot-assisted intervention. Furthermore, the use of robots in intervention for ASD children can be explored in other developmental domains such as motor skills and cognitive skills. Lastly, different aspects of elements (e.g. social interaction, appearance, visual and hearing sensitivity) should be taken into account when developing a new robot specific for ASD children.

6. CONCLUSION

This review aims to look at the current robots that are being implemented for intervention of ASD children. The literature indicates that the use of robots as socially assistive tools can improve the children's engagement and social interaction skills. Although improvement in skills can be noted across the literature, more studies should be focused on the implementing robots in the intervention targeted for motor skills. These insights are important for future study on intervention for ASD children.

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