Social Robots in Education to Enhance Social Communications and Interaction Skills of Children with Autism - A Review

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Abstract. Background: Social robots are a promising educational assistive tool for enhancing social interaction and empowering learning capability in children with autism spectrum disorders (ASD). **Objective:** This article reviews the use of social robots in education to enhance the social communication and interaction skills of children with autism. **Methods:** Twenty-two articles were identified and later analysed and synthesised. This study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. **Results:** The literature addresses several benefits of using social robots for children with ASD to enhance communication and interaction skills in children with ASD. These include human-like appearance acceptance, increased gesture and eye contact, structured learning and repetition, interpersonal synchronisation and emotions, use of interactive scenarios, reinforced behaviour and reward, ASD level and diagnosis. However, there are challenges also mentioned in the literature. **Conclusion:** The use of social robots in children with ASD is still in the early research phase and has been shown to provide several benefits for children with ASD. However, it is essential to consider the children's autism level before expecting any positive results from robotic intervention. In addition, several ethical challenges and implications must be considered before fully implementing social robots for children with ASD.

Keywords: Autism, social robots, education, social communication, children.

1 Introduction

According to some studies, incorporating robots in learning impacts children and indicates enormous possibilities and opportunities in educational systems [1–3]. Socially assistive robotics (SAR) are robots well-known for their ability to interact with humans, as they provide a common interactive platform for both humans and robots [4, 5]. Social robots use artificial intelligence, and it is paired with sensors, cameras, microphones and similar technology to interact and engage with humans [6].

SAR are promising as an assistive tool for enhancing social interaction and empowering learning capability in children with Autism Spectrum Disorders (ASD) [7, 8]. The World Health Organization (WHO) mentions that assistive technologies are critical enablers of inclusion and participation, including people with autism [9]. SAR include a wide range of features that could offer a more personalized experience for children with ASD than other Information and communication technology (ICT) solutions [10].

Robotic intervention plays an influential role in developing communication and interactive skills in ASD children [11] through effective intervention [12]. Social robots may improve children's learning abilities in child education by providing personalised lessons and individual progress reports [13].

Children with ASD tend to have poor social communication and interaction skills, and SARs can help bridge the gap and influence their participation through an interactive and personalised learning platform. Robots are used for interactive sessions, enabling learners to improve motivation and engagement with learning materials and facilitating teachers with new learning-aided tools [14].

In 1943, Kanner [15] first identified the term autism and characterised it as the inability to link with other people. ASD is a neurodevelopmental disorder, and yet its causes are a mystery. The severity of autism is categorised into three different levels, ranging from mild to severe [16, 17]. A wide range of impairments are associated with autism, including social communication and interaction, cognitive development, and repetitive behaviour [18]. Social interaction is one of the phenomena that directly and indirectly impact individuals with ASD; these include speech, language, conventions, and interpersonal skills [19].

Social robots have restricted behaviour and use simplified methods of delivering instructions, presenting information, predictable behaviour, and embodiment of the robot, human-like social cues. This helps ASD children learn social skills since ASD children usually lack adaptive behaviour, and ASD children do not need to deal with the complexity of human behaviour. Furthermore, studies have reported that physical interaction with robots is more engaging than screen-based technologies [12].

In Norway, the Norwegian Computing Center (NR) is conducting a project called The Robot Supported Education for Children with ASD (ROSA). The project aims to "create and evaluate a robot-based toolbox for teachers that can tailor content and learning for the unique needs of each child with ASD" [20]. The social robot is meant to act as a learning-aided tool to empower ASD children with social and communication interaction deficiencies in learning skills.

2 Methods

2.1 Aim

This research aims to describe how social robots in the education field can enhance the social communication and interaction skills of children with ASD.

2.2 Design

The literature review of this study is reported by following the general guidelines of the Preferred Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines. The PRISMA flow diagram presents the selected articles (Figure 1).

2.3 Search Process

The Academic Search Premier IEEE Xplore, Science Direct, SAGE, PubMed and Nature databases were searched in January and February 2022. The range of the search was from 2012-2022 and 133 articles were found. An updated literature search was conducted in August 2023, and only one article was added from the updated search (N=1). Therefore, a total of 134 articles were found. Journal articles and conference proceedings in English were chosen. The following search terms were used: ASD child, interaction, robot, social, and lesson to identify all relevant papers. A total of 22 articles were added and reviewed.

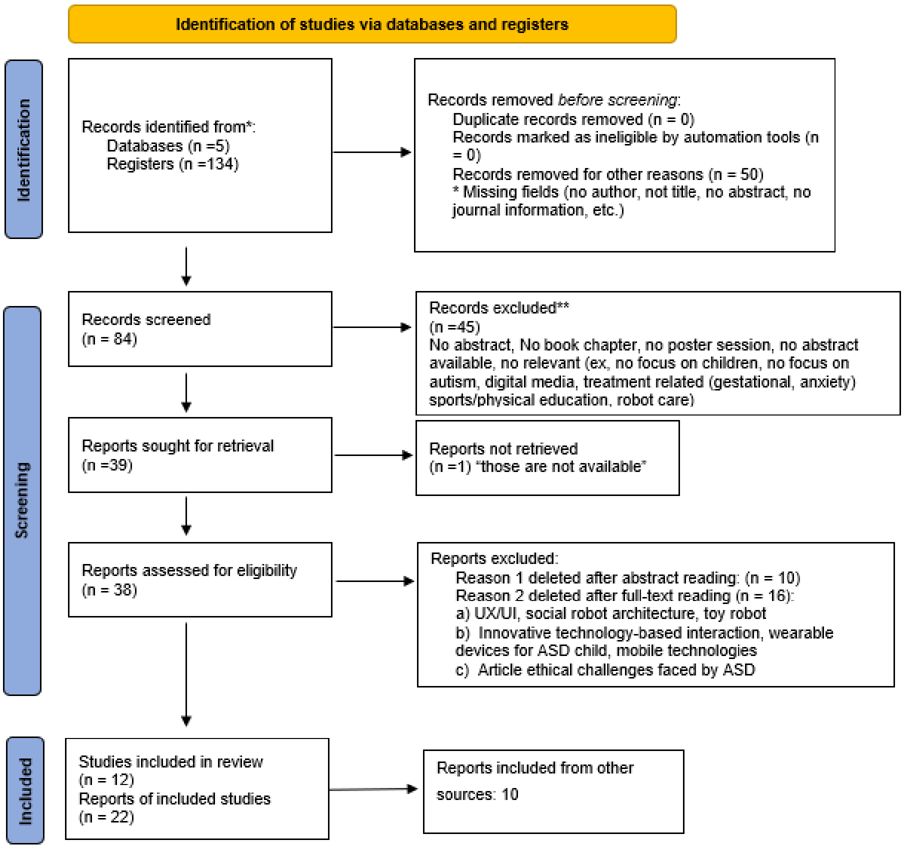

Fig. 1. PRISMA flow diagram of the selection process.

2.4 Data Selection

The search returned articles across the five mentioned databases [N=134]. The articles were screened first based on title and keywords. The inclusion criteria were 1) social robot to teach social and communication interaction skills to children with ASD, 2) child-robot interaction in terms of teaching social skills, 3) social robot intervention during teaching, therapy and school curriculum, 4) focus on ASD children regardless the severity level of autism 5) only studies available in full text in peer-reviewed journals or conference proceedings 6) year range 2012-2022 7) articles written in English. The following exclusion criteria were applied: 1) missing fields: no author, no title, no abstract, no journal information; 2) book chapters, poster session, no abstract available; 3) not relevant (no focus on children, digital media, gestational, no sports or physical education, robot care, no focus on autism, anxiety treatment, on adult/youth ASD). After the first screening, the number of papers was reduced to [N=39]. One (N=1) article could not be retrieved.

From the 38 articles, ten (N=10) articles were deleted after abstract reading. This resulted in 28 articles read in full text. Then, 16 articles were excluded for the following reasons: a) the studies based on designing computer interaction, designing robot UX/UI, social robot architecture, and toy robots; b) studies include innovative technology-based interaction, wearable devices for ASD children, mobile technologies, mobile application based persuasive technology to teach social skills, sensor-based learning devices, computer-based interaction, tablet/iPad based social skills learning c) article with focus on ethical challenges faced by ASD school administration and copy number of gene and clinical information.

Twelve articles (N=12) met inclusion and eligibility criteria, and ten (N=10) articles from other sources met both inclusion and eligibility criteria. These10 articles were found through colleagues, browsing reference lists, and the ROSA project published articles at NR and USN. Thus, a total of (N=22) articles are included in this review.

2.5 Data Analysis

The articles were analysed using thematic analysis as described by Braun and Clarke [21]. Firstly, the authors familiarized themselves with the data. This involved reading several times the articles included in this review. Then, initial codes were generated by coding as many potential themes or pattern as possible. The initial codes are shown in the Appendix, where table for each included article was extracted with their initial codes. Thirdly, themes were search in among the codes. Fourthly, the themes were reviewed by selecting candidate themes. Twelve candidate themes were found which were later reduced to eight. The themes were named by identifying the "essence" of the theme [21]. Themes were determined from the articles to understand the underlying meaning and their connections with social robot intervention in teaching ASD children social interaction and communication skills. Lastly the results were produced.

3 Results

Themes	No.of reports
ASD level	7
Human-like appearance and acceptance	5
Motivation, reinforced behaviour and reward	5
Gesture and eye contact	2
Structured learning and repetition	3
Interpersonal synchronisation and emotions	2
Interactive scenarios	3
Challenges	2

Table 1: Number of publications related to the themes.

The following topics were found in the literature: human-like appearance and acceptance, gesture and eye contact, structured learning and repetition, interpersonal synchronisation and emotions, interactive scenarios, motivation reinforced behaviour and reward, ASD level, and challenges. Table 1 shows the number of publications related to the themes.

Human-like appearance and acceptance: The design of the robots play in important role when using SAR for children with autism. It is reported that SAR has a higher acceptance rate in ASD individuals than in non-ASD individuals [22–24]. A wide range of social robots have been developed with human-like appearances, such as Kasper, FACE, Robota, Aibo, Charlie, NAO, etc. Social robots make simple emotional responses, which is an essential factor for effective communication and valuable to reduce the motivational and sensory barriers to some extent faced by children with ASD [22, 25]. Moreover, several types of robots in terms of their dimensions to be developed, such as Lego Mindstorms and NAO robots, are suitable for enhancing cognitive and social skills. In contrast, KIBO facilitates children to engage with cognitive, emotional and social objectives all together [26]. These robots use artificial intelligence.

Raptopoulou [23] stated that anthropomorphic robots are prevalent among education researchers due to non-distractive, approachable features and perused child interest. This is related to human beings' inherited responses towards technologies, where human-appearance technology is more attractive than machine-appearance technology. Moreover, the acceptance and trustworthiness of robots are directly related to the robot’s ability to show emotion. This mimics human-human interaction, which “facilitates natural communication and social interaction” [24]. Emotionally expressive robots impact verbal communication. Humans tend to prefer verbal and emotional communication with robots if the robot demonstrates human-like voice styles, gender, accent and prosody [24]. Robot anthropomorphism appearance and voice styles significantly influence humans to communicate with robots [22]

On the other hand, the absence of naturalness in the robot's appearance affects the user’s perception. “Introverts and those with lower emotional stability had a greater tendency to prefer a mechanical appearance”[24]. Others perceived the robot’s human-like appearance as frightening and uncomfortable. Despite this fact, humans show more enthusiasm and acceptance of the dynamic nature of emotional expression and movement of humanoid robots.

It has been reported that ASD child shows a preference for robots over humans [24]. However, the literature also mentions that measuring the child's preference for robot interaction and evaluating the degree of acceptability rely on surveys and often lack information regarding the benefits of using robot interaction over human interaction [26]. It also lacks the habitually and sustainability of the robot acceptance. Moreover, teachers' and parents' voices are emphasised to report children's experiences with robots. This is because children with ASD are unable to express their own robotic experiences by themselves [26]. Raptopoulou et al. [23] suggested an experimental protocol with a series of sessions. In the first few sessions, the child's acceptance of the robot was the focus. The other sessions focused on making a more comprehensive conclusion along with follow-ups to measure the reliability of the result.

Remarkably, teachers have accepted the robot's interaction methods and robot-based learning scenarios designed to contribute as a learning tool in the classroom [22].

Gesture and eye contact: A study compared the learning outcomes in ASD children "from robot-based intervention on gestural use to those from human-based intervention" [27]. The results showed no significant difference regarding gestural learning, stating that "it does not matter who serves as teaching agents when the lessons are highly structured" [27]. However, an exciting finding in the study was that teachers noticed higher eye contact in the children who received robot-based training. In addition, human and robot-based teaching helps train gestural recognition and production skills. Moreover, ASD children are more enthusiastic about learning from their robot partners, making less stereotypical behaviour when interacting with robots than humans, which aligns with the *social motivation* theory of autism. This theory states that ASD individuals lack of engagement skills with humans.

Another study used robot-based drama intervention gestural training in Chinese-speaking children with ASD [28]. The study found significant improvement in the ASD children's narrative abilities such as length, syntactic complexity, narrative structure, cognitive inferences and overall gestures and gestural communication compared to those who did not receive the intervention [28]. The robot-based play drama helped children to understand the characters' goals and their actions; later on, the ASD children were able to interpret the events of the drama by making cognitive inferences in their narrations as well as identifying the patterns and sequences even though they produce low effective inferences. Afterwards, ASD children from the intervention group participated in the role play to have practical experiences about the characteristics and their cognitive meaning with the patterns and sequence of life. The highly structured drama provided children with a sequential and predictable framework to maintain long-term comprehension of their own narratives.

Gestures made by social robots in the drama influenced children with ASD to adopt those gestures and motivated them to incorporate those gestures in the appropriate context. ASD children's gestures were made spontaneously and enhanced their understanding ability. However, this was limited to deictic gestures, not iconic or marker gestures demonstrated by the social robot in the drama play [28].

Structured learning and repetition: Another finding in the literature aligns with the *empathizing-systemizing* theory, which means that ASD children learn through highly structured lessons and produce positive learning outcomes [29]. Moreover, the *intense world theory* also states that children with ASD have positive learning outcomes in highly structured learning environments [27]. ASD children require a systematic approach and intervention to develop social and communication skills from human or robot-based intervention. Social robots have an advantage here since their features are systematic and predictable, repetitive in information sharing with children and maintain consistency throughout learning sessions [27, 28]. Children's engagement was noticed in robot-based drama as robots played the roles in a systematic, organised and predictable manner, therefore meeting the learning requirements of ASD children [28].

Interpersonal synchronisation and emotions: The study conducted by Giannopulu et al. [17] on interpersonal synchronisation of ASD children with robots in France and Japan provided outstanding results. Higher autonomic reactions were reported while using robots, and autonomic reactions were recorded similarly in children from different countries.

Interpersonal synchronisation was reported differently while French and Japanese children interacted with the same human perceiver. However, children from both France and Japan reported analogous and better emotions after interacting with robots than before interaction. Significant indifference in empathetic reactions was observed between neurotypical and ASD children from both countries. This was not due to the cultural differences but rather to the heterogeneous nature of the autism spectrum and autonomic activities of ASD children who are based on the intensity of "predictability and unpredictability or the level of intentionality of the perceiver"[17]. Additionally, ASD and neurotypical children perform similar autonomic reactions with robot perceivers. Empathetic reactions in terms of verbal and nonverbal are higher. ASD children seemed to better synchronise with robots than human partners, which directly contributed to improving ASD children's feelings.

Interpersonal synchronisation and emotional empathy are linked with autonomic reactions, directly or indirectly connected to cortical areas (prefrontal, temporal, and cingulate). It is also associated with empathy in neurotypical children, similar to ASD children when interacting with robots rather than humans. ASD child interaction with robots increases "mobilizations," resulting in children's engagement and spontaneous interaction with a robot partner. This is aligned with the "human inclination to enact in synchrony with machines or humans without being aware of it" [17].

Children with ASD tend to have difficulties expressing their own emotions and interpreting other's emotions. Emotional robot-oriented learning is encouraging for ASD children because robots can play a reinforcer role in learning and sharing experiences with others. A robotic intervention designed to elicit an ASD child's social interaction skills motor and vocal skills, along with multiple sensory experiences, is used to identify a child's affective state [24].

Notably, robots offer a low social and emotional load compared to humans. A study found that low social and emotional load allows children with ASD to have better "interpersonal synchronisation at an automatic level" [17]. In addition, ASD children maintained nonverbal communication with robots in a similar way as neurotypical children do with humans [17].

Interactive scenarios: Interactive scenarios significantly enhance social and communication skills in ASD children. In a study, robotic intervention helped children overcome this problem remarkably [22]. Robotic interactive scenarios based on the preschool curriculum with simple words were used to enhance the child's understanding and communication skills. The behaviour analysis approach was used to meet the learning demands of ASD children [22].

Child-robot interaction tends to encourage ASD children to interpret social cues produced while interacting with the robot, and this learning could be beneficial for ASD children in their interpersonal interactions in general [25]. Moreover, a robot can initiate prosocial behaviour where children interact directly with the robot, which is controlled without a remote. In this context, a robot could be assigned roles such as teacher, prompter, and assistant, among others [25].

Studies have pointed out that a lower parent rating is recorded due to a lack of direct robot reinforcement, and the game scenarios were either too easy or too complicated for an ASD child [30]. Furthermore, if the robot is less autonomous and the game scenario is predictable, a child with ASD will refuse to accept it. The challenging nature of robot-assisted scenarios can be reduced by using flexible robot behaviour to support a collection game library with various complexity levels to meet the needs of ASD children and allow therapists to adjust as needed during therapy sessions [30].

Motivation, reinforced behaviour and reward: *Applied behaviour analysis* (ABA) therapy consist of reinforcing specific behaviour so that the ASD children will repeat them [31]. Breaking down the target behaviour into structured and achievable steps is helpful for ASD children to learn and get rewarded each time they approach the correct action.

A study showed that ASD children preferred to receive rewards from their robot partners compared to praises from humans. In addition, the robots' appealing features improve the reward's effectiveness without serving as a motivator [25]. In contrast, robotic intervention can reduce undesirable behaviour but only for mild and no intellectual deficit children [25]. The same study also mentioned sensory aversion and inter-individual heterogeneity, meaning that the robot's attractive features (lighting signals, noisy functioning) draw the child's attraction. However, the *intense world theory* of Autism states that some ASD children may turn away from the robot due to being hypersensitive to these stimuli, for instance, auditory-sensitive children [25]. Therefore, it is better to focus on personalised and individual intervention methods instead of a general one. The same study suggested that adding more sensory options and educational goals in robots helps to personalise education [25].

Another study compared the effects of rhythm and robotic interventions on repetitive and affective states of ASD children [32]. The results showed that ABA-based intervention in school settings positively reduces the challenging behaviour of ASD children. The use of robot in child intervention makes the procedure simple, helps to mediate the learning environment, initiate interaction with a social partner, and enhance children's social communication and motor skills. Predictable characteristics of robot-child interaction allow children with ASD to learn in a highly motivating and manageable manner. In contrast, adult-child interaction is characterised as a complex, conventional and variable learning environment. [32]

Children's interest and motivation are important for accepting robotic intervention. A study combined motivational components of Pivotal Response Treatments (PRT) and robots to measure the likability of children and parents robotic intervention therapy [30]. However, the outcomes shed light on the fact that children with high ASD severity showed lower positive affect ratings after the robot-based session as they liked the human-based session more. ASD children are familiar with PRT therapy characteristics, emphasising the careful selection of robotic motivational features which best serve the child's interest.

Several robotic features associated with speech, movement, and game scenarios influence children's motivation. In other words, robots' nonverbal communication (i.e., waving hands, eyes blinking) motivates ASD children to engage in interactive communication with the robots. Furthermore, instruction with the visual assistance of the robot helps ASD children imitate the robot's movements [22]. Finally, contingent robots increase children's interaction and motivation as children find the robot responsive to their behaviour and conduct meaningful interaction [30].

ASD level: ASD severity may have an impact on the effectiveness of the intervention. The severity of autism is categorized into three different levels ranging from mild to severe. Mild level autism is identified as level 1 and severe as level 3. On the autism spectrum, mild level 1 autism is known as high-functioning autism and is frequently referred to as Asperger's syndrome. Level 2 is known as autism and demands substantial support, while severe level autism is categorized as Level 3 autism. People with level 3 autism suffer severely from social and communication deficiencies [16, 17].

Low-level ASD children's prosocial behaviour is higher with robotic intervention than those with severe ASD symptoms. According to the *social motivation theory* of Autism, ASD children are more drawn to robots than to human teachers, which can lead to a child's lack of interpersonal social skills [25].

Studies have shown that ASD children's communication and social interaction skills would be significantly impacted by pre-diagnosing and proper intervention [16, 33]. The severity level of autism is critical to determine the intervention methods and to meet individual ASD children's needs. However, this is demanding in terms of clinical settings, which opens doors for social robot intervention to treat autistic children [16, 34]. In addition, there is a lack of standard methodology for assessing the level of autism. As a result, researchers name them high/low, intermediate state, IQ scores and a plethora of weighted tests.

Different intervention approaches such as the *Early Start Denver Model, Pivotal Response Treatment, Pivotal Response Treatment, and parent- /peer-mediated therapies* help children enhance social behaviour with a positive impact by reducing maladaptive behaviour. Therapies sustain 30-40 hours per week, and outcomes are not as satisfactory as desired for ASD children [32]. Therefore, robotic intervention is not only limited to teaching and training children in communication and social interaction skills. For this reason, robots are being used to identify the level of autism [16, 32, 34]. Ali et al. [16] research focused on multi-robot therapy to predict the level of autism using Hidden Markov Model (HMM). Multi-robot interaction without requiring a therapist was used to address core impairments: joint attention, imitation and HMM models were used to predict the level of autism in a child based on the former observable state. The accuracy rate was 76%, which was then tested with the Childhood Autism Rating Scale (CARS) by the physiologist. Therefore, integrating robots to categorise the severity level of ASD children has shown to be beneficial [16]. However, a wide range of spectrum disorders in ASD can deliver different outcomes on the same stimuli [23].

Challenges: Some challenges have been reported, such as collaboration issues [25]. To meet the standards of excellence, stakeholders should work together, which is challenging in the field of robotic assistance for ASD children. A multidisciplinary research is essential to successfully develop social robots, including "To develop robots in this field, technological and multidisciplinary research is needed in human-robot interaction (HRI), human-computer interaction (HCI), robot-assisted learning, privacy, and ethics." [10]. Moreover, there is fear among researchers considering the sensitivity of ASD children. Other reported challenges are technical difficulties, increased workload, training for the robot use and personal investment [25]. Finally, the most important challenge is related to the ethical aspect of using robots for children with autism. Among the ethical challenges mentioned are obtaining informed consent since children with ASD are not able to provide this. In addition, obtaining real user participation from the children, teachers, and parents for testing may be challenged to attain [10].

4 Discussion

This article reviews the use of social robots in education to enhance social communications and interaction skills of children with autism. The findings first indicate that it is important to consider the children's level of autism and the challenges they face during their social communication and interaction. Children with ASD struggle to understand emotion and lack motivation in social interaction with their human communication partner. ASD children also tend to suffer from anxiety and face complexities when dealing with human behaviour. In any social situation, ASD children are not able to see others as an individual and do not involve themselves in social communication and interactions. These social communication and interaction skills difficulties impact ASD children's education and social life.

Researchers propose introducing social robots to address the deficiencies in ASD children's social communications and intercommunication. Social robots are prevalently among researchers to teach children with ASD social communication and interaction skills. Social skills are critical to learning for ASD children because of the different social settings in which human beings are involved throughout life. Moreover, children with ASD have difficulty interpreting and using information on their own in the correct social context. Therefore, social robots can be used to enhance their interaction skills with robotic features.

Individuals with severe levels of autism face higher degrees of deficiencies in their social communication. Children with low levels of autism may actively interact with robot-based lessons and feel motivated and interested in learning sessions conducted by the social robot. However, children with higher levels of autism might not be interested in robot-based learning. In addition, children with severe autism are not able to understand their surroundings; they are not able to convey their feelings to others and tend not to feel any emotion for an individual. Presenting a robot to a child with a high level of autism may be overwhelming and time-consuming to have any effective results.

Prosocial behaviour of children with low ASD is significantly higher than in children with high levels of autism. It is mentioned in the result chapter that ASD has a broader spectrum of disorders that cause the same stimuli to produce different results.

The efficacy of assistive technologies in terms of social robots is enormous, and their implications in teaching children social communication and interaction have piqued the interest of social robot researchers. Since children with ASD are deficient in learning adaptive behaviour, SAR can play an essential role in helping children develop their social skills by offering restricted robotic behaviour and simplified ways to present information to the children. During interaction with a robot partner, children with ASD learn to interpret social cues, which helps children develop their interpersonal interaction skills.

Moreover, the literature suggests that there are several robot features associated with child motivation, such as speech, movement, responsiveness towards child behaviour and ability to conduct a meaningful interaction. These features should be considered when introducing social robots in education for children with ASD. On the other hand, if an adult needs to control the robot or convey a message every time they interact with the robot, it would be complicated for ASD children to maintain multiple stages of communication since children with ASD have difficulty in one-to-one interaction.

Children with ASD need a safe and systematic approach to learn social communication and interaction skills. Hence, a social robot in education requires that it can enhance their learning motivation, help them to hold their interest in the learning content and track their learning progress for future reference. The literature shows that ASD children are interested in robots due to their predictable behaviour. It is easier for an ASD child to interpret a robot's systematic and constant movements because robots are pretty predictable. Hence, robots can perform the same task as often as the child requires and maintain the same approach to repeat the task, which benefits children with ASD.

According to empathizing-systemizing theory, ASD children can quickly learn through a systematic learning platform. Robots may produce better outcomes as robots are predictable, systematic, repetitive, and consistent in terms of communication and interaction. Robots can help tell social stories and play drama based on social situations while producing similar gestures or emotions with an exact tone every time. This is beneficial as robots can repeatedly show children how to do some tasks in specific ways without getting tired compared to humans while avoiding the human emotional load.

Finally, not many ethical challenges were found in the literature. This could be due to the search term combination, journal, or similar. However, it is vital to address that there is a lack of ethical considerations in the articles included in this review. When implementing assistive technology for a vulnerable group, i.e., social robots for children with autism, it is always important to consider the ethical aspects, so it does not hinder the full implementation of the technology.

5 Conclusions

In the era of technology, multiple digital devices are used to help develop ASD children's social and communication skills. However, the social robot plays the most crucial role because its human-like appearance, voice, and verbal and nonverbal gestures influence children to engage physically in communication rather than individual interaction with screen-based technologies. Several articles have pointed out that structured learning, predictable robotic features, contingency robots, repetition, and reward-giving by robots can be used in education to enhance ASD children's communication and interaction skills. Nevertheless, it is essential to consider the children's autism level before expecting any positive results from robotic intervention. Also, ethical challenges must be considered before fully employing social robots in education to enhance communication and interaction skills in children with ASD.

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Appendix

#	Authors and year	Title	Type of paper/study	Journal	Codes
1	(Jeon, 2021)	Turning HART into HEART: Human Emotional AI/Robot Teaming	Theoretical: A guidance to design a better Human AI/Robot teaming	Proceedings of the Human Factors and Ergonomics Society Annual Meeting	Human AI/Robot teaming, affecting computing, Emotions and affect
2	(van den Berk-Smeekens et al., 2020)	Adherence and acceptability of a robot-assisted Pivotal Response Treatment protocol for children with autism spectrum disorder	Robot-assisted therapy protocol based on motivational components of Pivotal Response Treatment	Scientific reports	Motivation for social interaction and self-initiation, game scenarios with 7 level of complexity, 14 parent-child session, 4 parent session, 2 child's teacher session, component of PRT, motivational component robotics, social interaction, self-initiation, contingent robot, robot-child interaction, robot acceptability and likability robot-assisted therapy protocol, motivation, PRT, ASD child and parent acceptability ratings,
3	(So, Wong, et al., 2019)	Who is a better teacher for children with autism? Comparison of learning outcomes between robot-based and human-based interventions in	A Comparative study of robot-based and human based interventions to teach ASD child gestural communication	Research in Developmental Disabilities	Structured learning environment, human-based teaching, robot-based teaching, gestural training, eye contact, social motivation theory of autism, empathizing-systemizing theory

		gestural production and recognition			
4	(So, Cheng, et al., 2019)	Robot-based play-drama intervention may improve the narrative abilities of Chinese-speaking preschoolers with autism spectrum disorder	Experimental Pilot study: robot-based drama-play intervention	Research in Developmental Disabilities	Affective inferences, play drama intervention protocol, structured approach, role play, narration, imitate, gesture, motivation, eye contact
5		Ordered interpersonal synchronisation in ASD children via robots	Experimental analysis of interpersonal synchronization between ASD child and robot versus human form two different countries (France and Janpan)	Scientific reports	Interpersonal synchronization, Emotional empathy, autonomic reactions(heart rate, heart rate variability),spontaneous interpersonal synchronization Conscious vs Unconscious
6	(Hamzah et al., 2014)	Development of Interaction Scenarios Based on Pre-school Curriculum in Robotic Intervention for Children with Autism	Fundamental study to understand social effects of language learning scenarios through ASD child robot interaction	Procedia Computer Science	ABA, interaction scenario, per-school curriculum, English language, communicate and understand simple words
7	(Kostrubiec & Kruck, 2020)	Collaborative Research Project: Developing and Testing a Robot-	Collaborative research to test the effectiveness of	Frontiers in Robotics and AI	Pivotal training method(PTM), applied analysis of behaviour, sensory reward, prosocial

		Assisted Intervention for Children With Autism	the robot-assisted intervention		behaviour, social skills(requesting and turn taking), Intense World Theory of Autism
8	(Ali et al., 2021)	An Experimental Trial: Multi-Robot Therapy for Categorization of Autism Level Using Hidden Markov Model	Experimental study combing of existing Multi-robot-mediated Intervention Systems (MRIS) with Hidden Markov Model (HMM) in order to classify autism severity level	Journal of Educational Computing Research	Joint attention(visual, speech and motion), imitation(Move Forward", "Move Backward", "Raise Hands", "Hands Down), HMM, level of autism (minimal and mild autism) prediction, multi-robot interaction,
9	(Arshad et al., 2020)	Robots as Assistive Technology Tools to Enhance Cognitive Abilities and Foster Valuable Learning Experiences among Young Children With Autism Spectrum Disorder	Quantitative and Qualitative analysis	IEEE Access	Play-based learning activities, cognitive skills, non-formal therapy and learning, motor manipulation, supporting autism, action and reinforcement cycle, mathematics(place value learning), motivation, focus, immersed, assistive tool
10	(Vogt et al., 2017)	Child-Robot Interactions for Second Language Tutoring to preschool children	Theoretical provide design features of social robot to tech ASD child second language	Frontiers in Human Neuroscience	Situatedness, embodiment, Temporal Contingency, Semantic Contingency(children focus of attention, joint attention), gesture, feedback, tack learning progress, adaptively of emotional state,

11	(Srinivasan et al., 2015)	A comparison of the effects of rhythm and robotic interventions on repetitive behaviors and affective states of children with Autism Spectrum Disorder (ASD)	Systematic comparison of rhythm and robotic therapies using a randomized controlled trial (RTC) design	Research in Autism Spectrum Disorders	ABA-based intervention, repetitive behaviour, highly structured activities
12	(David et al., 2020)	Effects of a Robot-Enhanced Intervention for Children With ASD on Teaching Turn-Taking Skills	Single-case experiments represents a valuable and common methodology for clinical research	Journal of Educational Computing Research	Rhythm, robotic, Eye contact, High perform child in SHT have less benefit from RET, turn-taking,
13	(Efthymiou et al., 2022)	ChildBot: Multi-robot perception and interaction with children	Experimental	Robotics and Autonomous Systems	Perception module: audio-visual active speaker localization, 6-DoF object tracking, visual activity recognition(gesture and action recognition), distant speech recognition, modular approach of child robot interaction
14	(Desideri et al., 2018)	Using a Humanoid Robot as a Complement to Interventions for Children with Autism Spectrum Disorder: a Pilot Study	A Pilot study using ABA single-case design	Advances in Neurodevelopmental Disorders	active engagement, passive engagement, active non-engagement, ABA, facilitator, mediator, child preference
15	(Alves-Oliveira et al., 2016)	The Role that an Educational Robot Plays	Empathetic robot tutor designed and	Robot and Human Interactive	Robot role assigned by children(TD), perception, Facilitator, motivation,

			developed to teach children sustainability	Communication (RO-MAN)	empathetic, personalized learning approach, empathetic role, non-empathetic role, other roles(friends, classmates, stranger, neighbor), pedagogical strategy, NAO robot
16	(Halbach et al., 2021)	Robot-Enhanced Language Learning for Children in Norwegian Day-Care Centers	A case study to investigate the existing digital language learning using app and its enhancement by using NAO robot	Multimodal Technologies and Interaction	Robot role, language learning, NAO robot, gamification,
17	(Shamsuddin et al., 2012)	Initial Response in HRI- a Case Study on Evaluation of Child with Autism Spectrum Disorders Interacting with a Humanoid Robot NAO	Case study	Procedia Engineering	Initial response, behaviour, eye contact, NAO robot, joint attention, Human robot interaction
18	(Raptopoulou et al., 2021)	Human–robot interaction for social skill development in children with ASD: A literature review	Systematic Literature Review by using bibliographic research for article surveyed due to investigate human robot interaction used	Healthcare Technology Letters	Language disorder, anthropomorphic robot

			to enhance ASD child social skills		
19	(Pivetti et al., 2020)	Educational Robotics for children with neurodevelopmental disorders: A systematic review	A systematic review	Heliyon	Education robot, teachers and parents voice, engagement, social interaction
20	(Boucenna et al., 2016)	Robots Learn to Recognize Individuals from Imitative Encounters with People and Avatars	An experimental study	Scientific reports	Person recognition, mutual imitation, autonomous robot, cognitive development
21	(Albo-Canals et al., 2013)	Comparing two LEGO Robotics-based interventions for social skills training with children with ASD	An analysis of two comparable studies of LEGO robotic-based activities	Robot and Human Interactive Communication (RO-MAN)	Social skills, child preferences and motivation, child familiar, robots roles on turn taking, mediators, shared attention
22	(Schulz, T., Skeide Fuglerud, K, 2022)	Creating a Robot-Supported Education Solution for Children with Autism Spectrum Disorder.	Case study on ROSA robot for education	International Conference on Computers Helping People with Special Needs	Robot for the support on education in the areas of communication, language, and emotion