Exploring the Potentials of Robotics in Supporting Children with Autism Spectrum Disorder

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Abstract

Technological advances have facilitated robots to perform a variety of human-like functions which have steered the interest of educators, researchers, and practitioners to discover the potential advantage of using robots as an intervention for individuals with autism spectrum disorder. Through meta-analysis, this study provides research-based information with regards to the potentials of robotics in supporting children with the disorder, particularly with regard to their skills and its implications to their learning performance. A total of twenty-five peer-reviewed articles published in international journals are included - the majority of them use humanoid robots with social skills as the focus of their study. The majority of these articles declare the commendable potentiality of utilizing robots in supporting children with autism spectrum disorder to improve their target skills and enhance their present level of performance. It is recommended that future studies could investigate the use of robotics in an inclusive educational setting focused on the supervision and improvement of cognitive-behavioral skills of children under the spectrum.

Keywords: autism, humanoid, learning performance, meta-analysis, robots

Introduction

The World Health Organization [WHO] defines autism spectrum disorder (ASD) as a gamut of mild to severe conditions with "impaired social behavior, communication and language, and a narrow range of interests and activities that are both unique to the individual and carried out repetitively" (WHO, 2019, para 1). The prevalence of young learners being diagnosed with ASD continues to rise every year. This could be accounted for by expanded diagnostic criteria, improved assessment tools, or even increased societal awareness that several advocacy groups have championed over the last decades. The WHO (2019), in particular, published that one in 160 children is identified as having ASD, which concerns countries in the world regardless of economic stability or degree of industrialization. In the United States of America, an estimate of 222 per 10,000 children have the said condition, for Asian countries like Japan and China, there are 181 and 23 in 10,000 children, while for European territories comprising Belgium, the Netherlands, and Germany, it is approximated that 60, 48, and 38 in 10, 000 children are detected of manifesting ASD respectively (Elflein, 2020).

In the fifth edition of the *Diagnostic and Statistical Manual for Mental Disorders (DSM 5*), the most recent edition that the American Psychiatric Association has released, ASD is described as a neurodevelopmental condition manifesting persistent deficits in social competence and notable recurring behaviors that significantly affect the other domains of functioning (American Psychiatric Association [APA], 2013). Considering these characteristics, it can be concluded that implications could be present in the learning performance of children with ASD. Their lack of socio-emotional reciprocity can hamper special and general education teachers from making collaborative learning feasible. Due to the existence of stereotyped motor movements in some children with ASD and the manifestation of difficulties in processing sensory information, acquiring meaningful academic experience could be challenging for them. This is confirmed in the work of Sanz-Cervera et al. (2017), declaring that children who are diagnosed with ASD are more likely to display issues related to sensory and higher functioning in the school settings. The struggles of children with ASD to receive and respond to a specific sensory stimulus may impact their academic performance and learning experiences in school.

A study by Kumazaki et al. (2019) claimed that children who have ASD often deliver better performance when a robot is present and is accompanied by a human partner. The results of this research revealed an intensified social communication ability of the participants involved, whose ages ranged from five to six. This situation pushes both the special education and general education teachers in trying several pedagogical methods to stop this from happening. Extended efforts are even being exhausted outside school hours to assure families that teachers are doing their job the best way possible. Evidence-based techniques are being tested one after another to ascertain that no children with ASD would be left behind, resulting in teachers and researchers exploring the potentiality of technology-driven interventions. Several experts have already seen this enormous invasion of technology in special and inclusive education as a powerful tool. Specifically, the help of assistive devices such as sensory aids, computer software, and augmentative and alternative communication has shown some effectiveness in improving the present level of functioning of students with special needs. Learners with ASD benefit also from other latest advancements in technology such as robotics, as it enables children in the spectrum to respond to feedbacks when exposed to social contexts and interactive settings. Robotics are progressively becoming the center of attention in the realm of educational and clinical research. It is now being used to assist children with ASD, and studies are revealing positive reviews regarding this matter.

On the other hand, like any other emerging tool or technique, robotics is criticized for its limitations in transferring skills and supporting learners with ASD to succeed in school further. Citing the work of Alcorn et al. (2019), arguments were given focusing on three conclusive points: robots being perceived as unspontaneous yet freely participative in responses; robots performing a similar function to existing tools and, therefore, seen as indifferent to what teachers are currently using in the classroom; and the need for robots to be subjected to personalization depending on the curricular aims to target prior its adoption. The argument raised in this research somewhat balances the overwhelming remarks of other researchers in the utilization of specified technology in the classroom. The same authors emphasize that although the use of robots is likely to deliver intricate cost-benefit trade-offs and might intensify the readiness level of children to process information, it may also inhibit them from interacting with their teachers and peers, thus leaving a gap for educators and practitioners to decide if robotics could realistically result in statistically significant outcomes in the learning process of children with ASD, especially in the context of inclusive education.

The identified gap and the mixed results disclosed above paved the way for the present researchers to conduct a systematic review of literature. Considering the newly available studies focusing on robotics from 2016 to the present, the researchers examined the possible implications of its effect on the learning performance of children under the spectrum with the perspective that even though ASD is not a learning disability, it can still impact on students' learning. The consolidated peer-reviewed research studies were thoroughly scrutinized to explore the possibilities of employing robotics in inclusive educational and clinical settings. Hence, the following specific questions were asked:

> (1) What is the typology of the robots used in assisting children with ASD in terms of type, target age of the participant/s, and the participants' level of disability?
> (2) What are the effects of robotics in supporting children with ASD?;
> (3) What could be the implications of these effects to the learning performance of children with ASD?

Methodology

This study was conducted using the meta-analysis method through the accumulation of information, knowledge, and research findings. According to Gurevitch et al. (2018), meta-analysis has two distinct central goals, and the first "is to assess the evidence for the effectiveness of specific interventions…often over a relatively small number of studies (fewer than about 25). The second, quite different, fundamental goal is to reach broad generalizations across larger numbers of study outcomes" (p. 176). The researchers systematically combined significant data from several articles selected to develop more complex analyses and come up with several inferences and conclusions. Several international studies with valid and reliable results were included following the inclusion criteria. The goal of employing meta-analysis as a research method was taken into consideration in this current study to establish pertinent results and recommendations. Consequently, this research examined 25 studies in total that explored the potentials of robotics in supporting children with ASD, the latter goal was intended to appraise how robotics could be an impactful tool in involving children under the spectrum in the general education setting. The study, likewise, aimed to "estimate the heterogeneity of the effects, which indicates the consistency of the effect across studies" (Cheung & Vijayakumar, 2016, p. 122).

Inclusion Criteria

The criteria used for studies that were included in this recent study are:

(a) it has to be an article published in a peer-reviewed journal;
(b) its publication should be between 2016 -2020;
(c) at least one participant of the study is a child with ASD;
(d) the study used robotics in supporting child/ren with ASD;
(e) there is/are specific skill/s for improvement addressed in the study.

Data Analysis

The appropriate form specifically designed for this study was developed by the researchers. This form examined individual studies found in the research, aligned with meta-analysis and its suitability, compared the studies, and determined the statistical information and narrative data used in the research. Homogeneity was determined and differences between the studies were analyzed. The result sections of the included papers were examined for recurring ideas in the findings that were stated as criteria for potentials. These findings were analyzed using a meta-summary technique. Recurring ideas in the findings were labeled into criteria for potentials and the frequency of the found criteria was examined. This was done to develop a more accurate appraisal of the support of robotics to children with ASD in terms of skill development and its implication to their learning performance despite their sensory processing difficulty. Different variables were identified in which the potentials of robotics in supporting children with ASD were addressed. Analyses of these variables were made, and their results were reported. In this research, the authors focused not on the statistical significance of individual studies, but on the magnitude of the effects of robots in supporting children with ASD.

Results and Discussion

Research Question 1. What is the typology of the robots used in assisting children with ASD in terms of (a) type and (b) target age and level of disability?

Table 1: Characteristics of Robots and the Participants

Study Number	Author	Type/Given Name of Robot	Participant	
			Age	Level
1.	Aryania et al. (2020)	Humanoid robot (Arc)	Nine to 11 years old	With high-functioning ASD and intelligence quotient scores of ≥70
2.	Berk-Smeekens et al. (2020)	Humanoid robot (Nao)	Three to eight years old	With total intelligence quotient scores of ≥70
3.	Pennazio & Fedeli (2019)	Humanoid robot (Nao)	Nine years old	With high-functioning ASD, but with cognitive and language deficits
4.	Zhang et al. (2019)	Humanoid robot (Nao)	Five to eight years old	With intelligence quotient of 104.90
5.	Conti et al. (2018)	Humanoid robot (Nao)	Five to 10 years old	With concomitant manifestations of mild to profound intellectual disability

6.	Desideri et al. (2018)	Humanoid robot (Nao)	Nine years old	With severe to profound ASD due to intellectual disability and hearing loss
7.	Feng, Y., Jia, Q. & Wei, W. (2018)	Humanoid robot (Nao)	Five to six years old	Not specified
8.	Koch (2018)	Humanoid robot	Five to 12 years old	With concomitant manifestations of no to mild cognitive impairment
9.	Kumazaki et al. (2017)	Humanoid robots - Tele-operated	10 to 17 years old	With high-functioning ASD
10.	Mengoni et al. (2017)	Humanoid robot (KASPAR-Kinesics and Synchronisation in Personal Assistant Robotics)	Five to 10 years old	With intelligence quotient scores of ≥70
11.	Palestra et al. (2017)	Humanoid robot (Nao)	Eight to 19 years old	With verbal and/or nonverbal ASD
12.	Schadenberg et al. (2019)	Humanoid robot (Zeno)	Five to 12 years old	With moderate ASD
13.	Scassellati et al. (2018)	Social robot	Six to 12 years old	With nonverbal intelligence quotient scores of ≥70 (as determined by the Differential Ability Scales)
14.	Pennazio (2017)	Social robot (IROMEC - Interactive Robotic Social Mediators as Companions)	Not specified	With profound ASD
15.	Simut et al. (2016)	Social robot (Probo)	Five to seven years old	With intelligence quotient scores of ≥70 and performance level of 80 % in a preference under- standing task
16.	Attawibulkul et al. (2018)	Automatic mobile robot (Bliss)	Four to 12 years old	With scores of ≥ 18 in Pervasive Developmental Disorder Screening Questionnaire
17.	Valadão et al. (2016)	Automatic mobile robot (Maria)	Seven to eight years old	Not specified
18.	Kumazaki et al. (2018)	CommU robot	Five to six years old	Not specified
19.	Lebersfeld et al. (2019)	Animal-like robot (SAM - Socially Animated Machine); monkey	Four to 14 years old	With severe to high average cognitive abilities
20.	Bharatharaj et al. (2017)	Animal-like robot (KiliRo) System Architecture; parrot)	Six to 16 years old	Not specified

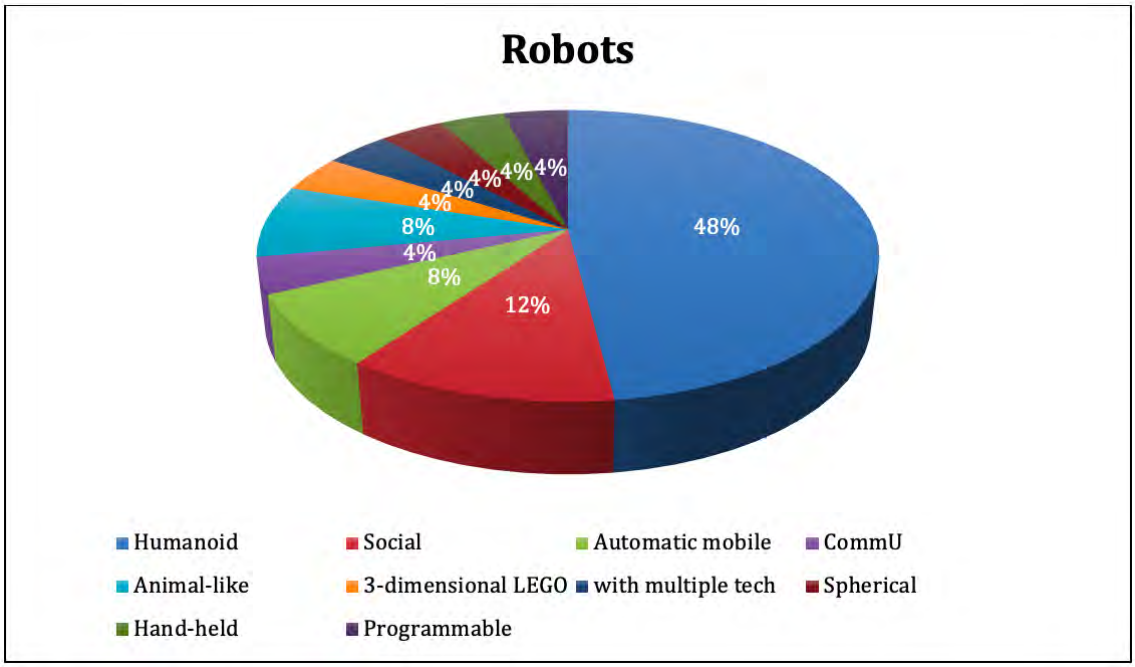
21.	Fachantidis et al. (2020)	Three-dimensional educational Lego robot	Nine years old	With concomitant manifestations of dysgraphia
22.	Kärnä, E., Dindar, K. & Hu, X. (2020)	Robots with multiple technology	Six to 12 years old	With concomitant manifestations of intellectual disability
23.	Kostrubiec, V. & Kruck, J. (2020)	Spherical prototype robot	Five to 10 years old	With low-functioning ASD
24.	Knight, V., Wright, J. & DeFreese, A. (2020)	Hand-held smart robot (Ozobot)	10 years old	With mild to moderate ASD and concomitant manifestations of attention deficit/hyperactivity disorder and emotional behavior disorder.
25.	Albo-Canals et al. (2018)	Programmable toy robot (Kibo)	Six to 14 years old	With severe ASD and cognitive impairments

Table 1 shows the characteristics of the robots and the participants of the study. From the 25 articles reviewed, it can be seen that different kinds of robots were used to provide support to children with ASD.

As regards the kinds of robots used, Figure 1 shows that 12 or 48% of the articles utilized humanoid robots in their experiments in handling children with ASD, such as Nao, Arc, Zeno, and KASPAR, and tele-operated robots. Typically, a humanoid robot has a physical appearance that is very appealing to children as it resembles the features of a small child and is also attentive to children (Ismail et al., 2019). Furthermore, Pennazio and Fedeli (2019) emphasized that humanoid robots with favorably interactive features can elicit more responses from children with ASD in terms of distinguishing and duplicating emotions. The presence of a robot resembling a human person, in this case, a small child, is important for children with ASD since they are generally characterized as having deficits in social skills. These robots can function as a playmate and companion to these children and can contribute to the development of their social skills. Cho and Ahn (2016) stated that technologically designed robots could develop suitable social interaction skills and behaviors among students.

The other types used were social robots, automatic mobile robots, animal-like robots, Lego robots, toy robots, CommU robots, and robots that can be held and programmed with multiple technologies. These types normally resemble animals or toys that children with ASD are familiar with. According to Cho and Ahn (2016), the robots may be presented in various designs provided that the purpose for their use is identified to target the deficits of children with ASD, such as improving concentration, facilitating joint attention, and modeling appropriate social behavior.

Moreover, the participants of the articles reviewed were children with ASD from ages three to 19 years old. They had either mild/moderate to severe/profound intellectual ability, low to high functioning ASD, verbal or non-verbal ASD, with cognitive and language impairments, dysgraphia, attention-deficit/hyperactivity disorder, and emotional disorder.



Research Question 2. What are the effects of robotics in supporting children with ASD?

Table 2: Robotics and Its Effects on the Targeted Skills of Children with ASD

Research Number	Targeted Skill/s	Effects
1.	Social (engagement behavior)	Child–robot interaction improved the social engagement of some children diagnosed under the spectrum.
2.	Social and Emotional (treatment adherence, child affect, and likability)	With the aid of the robot, participants displayed adherence during the treatment protocol and positive child affect. Also, commendable likability scores were noted due to robot movements, speech, and games.
3.	Cognitive and Social (emotional ability and self-confidence)	The humanoid robot and the further virtual interaction through avatars represented a highly adaptive method to simulate social stories that engaged the child on a cognitive and emotional level.
4.	Social (learn distrust and deception)	Involvement of humanoid robots in social rules training for children with ASD had a notable potential.
5.	Social (eye gaze, imitation, and educator involvement)	Four out of six participants exhibited progress in all the variables before and after the robot training. Only two participants struggled during the experiment due to the presence of a profound intellectual disability.
6.	Social and Language (vocal imitation, motor imitation, expressive language, receptive language, react to name, and spontaneous request)	The robot gave different effects on the participants involved in the study. The improvement level from baseline to post-intervention of the two participants varied depending on the variable tested.
7.	Social (robot awakes children's interest/attention by dancing, singing, dialogue, etc.)	Robot-assisted intervention, through the proposed control architecture, was considered efficient and successful in strengthening the socialization skills of the participants with ASD.

8.	Social and Emotional	Findings disclosed unfailing high ratings of happiness, improved comfort ratings, and only slightly declined ratings of desire for further interactions through time.
9.	Social (interaction / response)	The suitability of specific robot types (on the levels of ASD) and appearance (more human-like humanoid robots over mechanical or mascot-like) were preferred for therapeutic use.
10.	Social	The robot gave positive effects, offering the children the possibility to improve their social skills.
11.	Social and Language (social communication and social skills)	The presence of a robot helped facilitate in prompting triadic relations in ASD.
12.	Social (interaction)	Design of deliberate robot behavior and autonomy over the robot's behavior encouraged engagement and enabled more learning prospects for children with ASD.
13.	Social	The joint attention and communication competence of the participants were enhanced as the robot encouraged engagement.
14.	Social (eye contact, touch, facial expressions, human interaction)	The participant exhibited a remarkable increase in joint eye contact and facial expressions. Significant touch was also recorded, as the participant showed interest in hugging the robot. Imitation and interaction with the robot, teacher, and peers were demonstrated, which validated the affirmative effects of the robot in enhancing human interaction.
15.	Social and Language (eye contact, initiating joint attention, verbal utterances, positive affect, no-response, evading task behaviors)	No other significant differences were attained for the following: initiating joint attention, verbal utterances, positive affect, no-response, and evading task behaviors. Therefore, the robot showed a significant difference in an eye-contact variable when juxtaposed to the human partner.
16.	Cognitive (theory of mind and attention time)	There was no significant difference in supporting the theory of mind and the attention time during the session. However, the response time of the participants with the BLISS robot was shorter compared to when the robot was not present, which gave the parents an easier job when doing the storytelling activity.
17.	Social	The robot was useful in improving both the socialization and general quality of life potentials of the participants.
18.	Social	The children's interaction with robot CommU displayed better Joint Attention (JA) tasks with a human.
19.	Social (child's enjoyment, motivation, and willingness to interact)	Robot-based interventions were useful for skills acquisition of children with ASD because they found it encouraging and interesting.
20.	Cognitive, Social, and Language (Learning and social interaction abilities)	Generally, participants showed a gradual increase in terms of their satisfaction (happiness) level and degree of social interaction.
21.	Social, Language, and Emotional	The use of educational robotics was a promising tool to develop the social, communicational, and emotional skills of children with ASD.
22.	Social and Cognitive	The use of adaptable technologies during educational activities offered wide-ranging opportunities for the participants to practice communication and interaction skills.

23.	Social	The robot's sensory rewards produced more positive reactions from the participants compared to the verbal praises from humans. Likewise, educators had a positive view/attitude towards robotic support for evidence-based practice on children diagnosed with ASD.
24.	Psychomotor (acquisition of three skills: calibrating, drawing track lines, and coding)	The participant demonstrated the ability to reach 100% precision for all the skills tested. Further, he was able to generalize the coding skills to a novel exemplar with 100% correctness.
25.	Social	The participants were able to play individually and control the robot, which implied impressive engagement. Moreover, the children connected well with the adults present inside the room.

Table 2 reveals the targeted skills in all the articles gathered and the effects disclosed after the exposure of the participants to robots. In terms of skills, it could be seen that there were studies that addressed multiple skills in one research and others focused only on a specific skill. Considering the 25 studies included in this meta-analysis, 23 examined the use of robotics in supporting the social performance of children in the ASD category. This was more than three-fourths of the total number of papers analyzed for this present research. This was followed with language and cognitive skills, which were only directed in five and four studies, respectively.

Children who are diagnosed with ASD are known for their recognizable deficiencies in socialization, mainly in the aspect of socio-emotional reciprocity, interaction, and nonverbal communicative behaviors. The diagnostic criteria in DSM 5 support this as it accentuates the "persistent deficits in social communication and social interaction across multiple contexts" among children with ASD (APA, 2013, p. 50). This is followed by specific manifestations to clearly characterize people with the said condition, such as lack of eye gaze or contact, restricted imitation skills, reduced adherence, limited engagement, rigid emotions, and poor facial expressions. Remarkably, these manifestations were purposely targeted under social skills in some of the studies counted in this meta-analysis. This allowed the participants included in these studies to be more able regardless of their restraints, in establishing age-appropriate social competence. The intention to improve the most problematic skill among children with ASD gave an array of opportunities for them to attain a higher level of functional performance.

Concerning the language and communication skills, Wittke et al. (2017) indicated that children who are diagnosed with ASD may also manifest impairments or problems in language, predominantly in the component of pragmatics. More so, the presence of language delays among students in the spectrum is normal (Marrus et al., 2018) considering the struggles they are experiencing in processing language codes and in analyzing the social context of the situation. In relation to the cognitive skills, the inability to understand information and learn concepts is not listed as diagnostic criteria for ASD. Still, it cannot be disregarded that there are students with ASD who struggle in maximizing their executive functioning, such as planning, problem-solving, and reasoning (Center for Autism Research, 2020). These aforementioned arguments validate the language and cognitive problems of people with ASD, and therefore, being used as variables in some of the accumulated robotics-based studies can further fulfill the potentials of this disability population, particularly when the results of these studies gave general positive effects after the introduction of the robots to children with ASD.

The majority of the 25 articles declared the commendable potentiality of utilizing robots in supporting children with ASD. This technology-driven tool can improve the target skills and enhance the present level of performance of the individual studied. This finding is similar to all types of robots. The overall effects verify the applicability of robots in handling children with ASD, irrespective if the robots appear with humanoid features, automatic mobile elements, social components, animal-like structure, or spherical prototype. The study by Feng et al. (2018) highlighted not just the effectiveness of a robot-assisted intervention in intensifying the socialization skills of the participants, but also the decreased responsibilities of the supervisors or teachers in assisting children. This also aligns with the results of Scassellati et al. (2018) who mentioned the strengthened communication abilities and attention span of the participants with ASD, which included alleviated prompts of the caregiver since the existence of the robot during tasks. The social interaction and engagement of the participants were also enhanced during or after the sessions (Aryania et al., 2020; Bharatharaj et al., 2017; Kärnä et al., 2020; Palestra et al., 2017; Schadenberg et al., 2019), which contributes to the possible adaptation of robots in an environment where children with ASD are placed for therapy, education, or even in independent training. However, some studies provided limitations about the effects of a robotics-based intervention on children with ASD. The research of Desideri et al. (2018) specified that robots do not have an analogous degree of effect, as the conducted experiments produced varied results by the participants. Conti et al. (2018) agreed, as two of the six children with ASD included in their experiments encountered difficulties due to profound intellectual disability. Furthermore, the studies of Simut et al. (2016) and Attawibulkul et al. (2018) mentioned that the possible restriction of robotics can also include the definite skills to be addressed as no improvements were seen in the following: initiating joint attention, verbal utterances, positive affect, no-response, evading task behaviors, and supporting the theory of mind. These data with marginal differences between the pre-and post-intervention imply that the effects of robotics-based intervention may be dissimilar and reliant on the severity of the condition and the subskills under a target skill.

Research Question 3. What could be the implications of these effects on the learning performance of children with ASD?

Aside from the applicability of robots for therapy-related concerns, the results show an evident and effective way to facilitate different skills for children with ASD. Many different skills were targeted in the majority of studies scrutinized for this research. As a result, there is a significant increase in the previously seen problematic subskills of the participants.

Children with ASD find it difficult to communicate and interact with other people. With the premise that effective learning and teaching presumes effective social communication, the studies substantiated that the enhancement of socialization skills and communicative intents of children with the presence of robots is significant for the effective learning of students with ASD. The results show significant improvement in the interaction with humans after the interaction with robots, which equates to more successful communication and interaction which is the main concern of children with ASD. During educational activities, robots provide children with ASD with a variety of opportunities to practice communication and interaction skills. This may be regarded as key to better learning performance since it has been established that there is a significant correlation between communication in the classroom and academic performance of students (Fernandes, 2019). Based on the different articles examined, several factors contribute to the increase in performance of children with ASD in the classroom. An increase in motivation and attention is emphasized in many of the studies. Children with ASD are more motivated and more attracted to robots, which is useful for skill acquisition

(Lebersfeld et al., 2019). The attractive appearances of the humanoid robot seem to get more attention from children with ASD and help prevent fearfulness. This leads to a more engaging interaction where even if the attention time maybe the same, even without the robot, the response time is shorter (Attawibulkul et al., 2018), which will establish more interaction and learning.

Through the use of robots, there is an evident improvement in communication and social interaction. As a result, challenging behaviors that may limit the facilitation of learning are significantly lessened (Fachantidis et al., 2020). In relation to this, the result of interaction with robots is in the aspect of attention. Children with ASD give more attention to other people, following their previous experience of interacting with robots (Kumazaki et al., 2018).

The use of robots is an effective way to facilitate social skills for children with ASD, thus leading to the improvement of social skills and eliciting effective interactions. For instance, eye-contact is strengthened when the robot is partnered with a human (Simut et al., 2016). Interaction with robots promotes better adjustment to and understanding of change in what is happening in the surroundings, and this helps in better understanding of situations and in promoting learning in children with ASD (Pennazio & Fedeli, 2019).

Fundamentally, what is interesting to note is that robotics, aside from the improvements in socialization and improvement in learning performance, is useful for the improvement of the quality of life (Valadão et al., 2016) and satisfaction (happiness) level (Bharatharaj et al., 2017) of children with ASD.

Conclusions and Recommendations

The growing population of children diagnosed with ASD has been a pressing concern of educators and practitioners, which has led them to explore ways to create programs and interventions to improve the adaptive and functional skills of these children. One of the promising tools in therapeutic and educational interventions for children with ASD is the application of robotics. This perspective motivated the present researchers to conduct a meta-analysis to explore the potentials of robotics in supporting children with ASD and to determine its possible implications to the children's learning performance.

Based on the analysis of the identified variables in the current study, the researchers concluded that humanoid robots were largely used in experimental studies included in this meta-analysis for children with ASD irrespective of ages, levels of disability, and target skills. This robot typology was most likely appealing to the participants because of its physical appearance resembling the features of a child which may have been perceived as a playmate and companion that help prevent fear in interacting with others, thus contributing to the development and/or improvement of their social skills. Likewise, social skills were remarkably the foci of most of the studies conducted relative to the use of robotics in supporting children with ASD, followed by language and cognitive skills. The authors of the reviewed articles noted that technologically driven tools, such as robotics, have a commendable potentiality as an intervention in improving the target skills and in enhancing the present level of performance of the understudied. Although humanoid robots were mostly preferred, similar positive outcomes were attained with the other types of robots in the studies conducted, which implies that a robot with appropriately designed features according to its purpose, regardless of appearance, can be used as an intervention in supporting children with ASD. Moreover, the improved social, language, and cognitive skills of the children with ASD using robotics as intervention also indicate a

promising effect on their learning performance. Notably, the development of these skills has an impact on the learners' performance during the teaching and learning process since these could increase their ability to interact, establish positive relationships, communicate, pay attention, and improve self-esteem – factors that are highly necessary for improving their functional skills and learning performance. The robots can aid in increasing the motivation and attention of the students with ASD and provide them with a variety of activities to engage, communicate, and respond during educational activities.

Lastly, future research could delve into the use of robotics in an inclusive educational setting focused on the supervision and improvement of cognitive-behavioral abilities of students with ASD since literature is scarce in this aspect. Additionally, future studies may also investigate the use of robotics for a specific level of severity of the disability and subskills under a target skill/domain.

It is the hope of educators, practitioners, and researchers that various interventions being studied and implemented such as robotics will not only develop and enhance the adaptive, functional, and cognitive skills, and learning performance of the students with ASD, but most importantly to better their state of life that would eventually allow them to experience happiness in their existence.

References

Albo-Canals, J., Martelo, A. B., Relkin, E., Hannon, D., Heerink, M., Heinemann, M., Leidl, K., & Bers, M. U. (2018). A pilot study of the KIBO robot in children with severe ASD. *International Journal of Social Robotics*, *10*(3), 371–383. https://doi.org/10.1007/s12369-018-0479-2

Alcorn, A. M., Ainger, E., Charisi, V., Mantinioti, S., Petrovic, S. Schadenberg, B. R., Tavassoli, T. & Pellincano, E. (2019). Educators' views on using humanoid robots with autistic learners in special education settings in England. *Frontiers in Robotics and AI*, 6(107), 1–15. https://doi.org/10.3389/frobt.2019.00107

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5)*. American Psychiatric Pub. https://doi.org/10.1176/appi.books.9780890425596

Aryania, A., Aghdasi, H. S., Beccaluva, E.A., & Bonarini, A. (2020). Social engagement of children with autism spectrum disorder (ASD) in imitating a humanoid robot: A case study. *SN Applied Sciences 2(1085).* https://doi.org/10.1007/s42452-020-2802-4

Attawibulkul, S., Sornsuwonrangsee, N., Jutharee, W., & Kaewkamnerdpong, B. (2018). Using storytelling robot for supporting autistic children in theory of mind. *International Journal of Bioscience, Biochemistry and Bioinformatics*, *9*(2), 100–108. https://doi.org/10.17706/ijbbb.2019.9.2.100-108

Berk-Smeekens, I., Dongen-Boomsma, M., De Korte, M. W., Den Boer, J. C., Oosterling, I. J., Peters-Scheffer, N. C., Buitelaar, J. K., Barakova, E. I., Lourens, T., Staal, W.G. & Glennon, J. C. (2020). Adherence and acceptability of a robot-assisted pivotal response treatment protocol for children with autism spectrum disorder. *Scientific reports*, *10*(1), 1–11. https://doi.org/10.1038/s41598-020-65048-3

Bharatharaj, J., Huang, L., Mohan, R. E., Al-Jumaily, A., & Krägeloh, C. (2017). Robot-assisted therapy for learning and social interaction of children with autism spectrum disorder. *Robotics*, *6*(1), 4. https://doi.org/10.3390/robotics6010004

Center for Autism Research. (2020, June 9). *Executive function difficulties.* CAR Autism Roadmap. *https://www.carautismroadmap.org/executive-function/*

Cheung, M. W., L. & Vijayakumar R. (2016) A guide to conducting a meta-analysis. *Neuropsychology Rev 26,*121–128. https://doi.org/10.1007/s11065-016-9319-z

Cho, S. J., & Ahn, D. H. (2016). Socially assistive robotics in autism spectrum disorder. *Hanyang Medical Reviews*, *36* (1), 17. https://doi.org/10.7599/hmr.2016.36.1.17

Conti, D., Di Nuovo, A., Trubia, G., Buono, S., & Di Nuovo, S. (2018, March). Adapting robot-assisted therapy of children with autism and different levels of intellectual disability: a preliminary study. In *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, 91–92. https://doi.org/10.1145/3173386.3176962

Desideri, L., Negrini, M., Malavasi, M., Tanzini, D., Rouame, A., Cutrone, M. C., & Hoogerwerf, E. J. (2018). Using a humanoid robot as a complement to interventions for children with autism spectrum disorder: A pilot study. *Advances in Neurodevelopmental Disorders*, *2*(3), 273–285. https://doi.org/10.1007/s41252-018-0066-4

Elflein, J. (2020). *Prevalence of autism spectrum disorder among children in select countries worldwide as of 2020.* Statista. https://www.statista.com/statistics/676354/autism-rate-among-children-select-countries-worldwide/

Fachantidis, N., Syriopoulou-Delli, C. K., Vezyrtzis, I., & Zygopoulou, M. (2020). Beneficial effects of robot-mediated class activities on a child with ASD and his typical classmates. *International Journal of Developmental Disabilities*, *66*(3), 245–253. https://doi.org/10.1080/20473869.2019.1565725

Feng, Y., Jia, Q. & Wei, W. (2018). A control architecture of robot-assisted intervention for children with autism spectrum disorder. *Journal of Robotics Special Issue,* 1–12. https://doi.org/10.1155/2018/3246708

Fernandes, C., (2019) *The relationship between teacher communication, and teacher credibility, student motivation, and academic achievement in India* (UMI No. 10980753) [Doctoral dissertation, Concordia University, Portland]. ProQuest Dissertations & Theses Global database.

Gurevitch, J., Koricheva, J., Nakagawa, S., & Stewart, G. (2018). Meta-analysis and the science of research synthesis. *Nature, 555*, 175–182. https://doi.org/10.1038/nature25753

Ismail, L. I., Verhoeven, T., Dambre, J., & Wyffels, F. (2019). Leveraging robotics research for children with autism: A review. *International Journal of Social Robotics*, *11*(3), 389–410. https://doi.org/10.1007/s12369-018-0508-1

Kärnä, E., Dindar, K. & Hu, X. (2020). Educators' engagement with children with autism spectrum disorder in a learning environment with multiple technologies in Finland and China. *Interactive Learning Environments, 28*(1), 50–64. https://doi.org/10.1080/10494820.2018.1512002

Knight, V. F., Wright, J., & DeFreese, A. (2019). Teaching robotics coding to a student with ASD and severe problem behavior. *Journal of Autism and Developmental Disorders*, *49*(6), 2632–2636. https://doi.org/10.1007/s10803-019-03888-3

Koch, S. A. (2018). *Effectiveness and acceptability of a robot-based social skills intervention for children with autism spectrum disorder* (UMI No. 10598918) [Doctoral dissertation, University of Alabama]. ProQuest Dissertations & Theses Global database.

Kostrubiec, V. & Kruck, J. (2020). Collaborative research project: Developing and testing a robot-assisted intervention for children with autism. *Front. Robot. AI 7:37*. https://doi.org/10.3389/frobt.2020.00037

Kumazaki, H., Muramatsu T., Yoshikawa, Y., Yoshimura, Y., Ikeda, T., Hasegawa, C., Saito, D. N., Shimaya, J., Ishiguro, H., Mimura, M., & Kikuchi, M. (2019). Brief Report: A novel system to evaluate autism spectrum disorders using two humanoid robots. *Journal of Autism and Developmental Disorders* (2019) *49*(4) 1709–1716. https://doi.org/10.1007/s10803-018-3848-7

Kumazaki, H., Yoshikawa, Y., Yoshimura, Y., Ikeda, T., Hasegawa, C., Saito, D. N., Tomiyama, S., An, K., Shimaya, J., Ishiguro, H., Matsumoto, Y., Minabe, Y., & Mitsuru K. (2018). The impact of robotic intervention on joint attention in children with autism spectrum disorder. *Molecular Autism 9*(46), 2–10. https://doi.org/10.1186/s13229-018-0230-8

Kumazaki, H., Warren, Z., Muramatsu, T., Yoshikawa Y., Matsumoto Y., Miyao, M., Nakano, M., Mizushima, S., Wakita, Y., Ishiguro, H., Mimura, M., Minabe, Y., & Kikuchi, M. (2017). A pilot study for robot appearance preferences among high-functioning individuals with autism spectrum disorder: Implications for therapeutic use. PLoS ONE 12*(10):* e0186581. https://doi.org/ 10.1371/journal.pone.0186581

Lebersfeld, J. B., Brasher, C., Biasini, F., & Hopkins, M. (2019). Characteristics associated with improvement following the sam robot intervention for children with autism spectrum disorder. *International Journal of Pediatrics and Neonatal Care, 5*(151). https://doi. org/10.15344/2455-2364/2019/151

Marrus, N., Hall, L. P., Paterson, S. J., Elison, J. T., Wolff, J. J., Swanson, M. R., Parish-Morris, J., Eggerbrecht, A. T., Pruett, J. R., Hazlett, H. C., Zwaigenbaum, L., Dager, S., Estes, A. M., Schultz, R. T., Botteron, K. N., Piven, J., & Constantino, J. N. (2018). Language delay aggregates in toddler siblings of children with autism spectrum disorder. *Journal of neurodevelopmental disorders*, *10*(29). https://doi.org/10.1186/s11689-018-9247-8

Mengoni, S. E., Dautenhahn, K., Sharma, S., Guldberg, K., Robins, B., Wellsted, D., Irvine, K., Thakur, D., & Barton, G. (2017). Feasibility study of a randomised controlled trial to investigate the effectiveness of using a humanoid robot to improve the social skills of children with autism spectrum disorder (KASPAR RCT): A study protocol. *BMJ Open, 7*(6):e017376. https://doi.org/10.1136/bmjopen-2017-017376

Palestra, G., Cazzato, D., Adamo, F., Bortone, I., & Distante, C. (2017). Assistive robot, RGB-D sensor and graphical user interface to encourage communication skills in ASD Population. *Journal of Medical Robotics Research*, *02*(02), 1740002. https://doi.org/10.1142/s2424905x17400025

Pennazio, V. (2017). Social robotics to help children with autism in their interactions through imitation. *Research on Education and Media*, *9*(1), 10–16. https://doi.org/10.1515/rem-2017-0003;

Pennazio, V., & Fedeli, L. (2019). A proposal to act on theory of mind by applying robotics and virtual worlds with children with ASD. *Journal of E-Learning and Knowledge Society*, *15*(2), 59–75. https://doi.org/10.20368/1971-8829/1632

Sanz-Cervera, P., Pastor-Cerezuela, G., González-Sala, F., Tárraga-Mínguez, R., & Fernández-Andrés, M. I. (2017). Sensory processing in children with autism spectrum disorder and/or attention deficit hyperactivity disorder in the home and classroom contexts. *Frontiers in psychology*, *8*, 1772. https://doi.org/10.3389/fpsyg.2017.01772

Scassellati, B., Boccanfuso, L., Huang, C.-M., Mademtzi, M., Qin, M., Salomons, N., Ventola, P., & Shic, F. (2018). Improving social skills in children with ASD using a long-term, in-home social robot. *Science Robotics*, *3*(21), eaat7544. https://doi.org/10.1126/scirobotics.aat7544

Schadenberg, B. R., Reidsma, D, Heylen, D. K. J., & Evers, V. (2020). Differences in spontaneous interactions of autistic children in an interaction with an adult and humanoid robot. *Front. Robot. AI 7*, 28. https://doi.org/ 10.3389/frobt.2020.00028

Simut, R. E., Vanderfaeillie, J., Peca, A., Van de Perre, G., & Vanderborght, B. (2016). Children with autism spectrum disorders make a fruit salad with probo, the social robot: An interaction study. *Journal of Autism and Developmental Disorders*, *46*(1), 113–126. https://doi.org/10.1007/s10803-015-2556-9.

Valadão, C. T., Goulart, C., Rivera, H., Caldeira, E., Bastos Filho, T. F., Frizera-Neto, A., & Carelli, R. (2016). Analysis of the use of a robot to improve social skills in children with autism spectrum disorder. *Research on Biomedical Engineering*, *32*(2), 161–175. https://doi.org/10.1590/2446-4740.01316

Wittke, K., Mastergeorge, A. M., Ozonoff, S., Rogers, S. J., & Naigles, L. R. (2017). Grammatical language impairment in autism spectrum disorder: Exploring language phenotypes beyond standardized testing. *Frontiers in psychology*, *8*, 532. https://doi.org/10.3389/fpsyg.2017.00532

World Health Organization (WHO, 2019). *Autism spectrum disorders.* World Health Organization. https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders

Zhang, Y., Song, W., Tan, Z., Zhu, H., Wang, Y., Lam, C. M., Weng, Y., Hoi, S. P., Lu, H., Chan, B. S. M., Chen, J., & Yi, L. (2019). Could social robots facilitate children with autism spectrum disorders in learning distrust and deception? *Computers in Human Behavior 98,* 140–149. https://doi.org/10.1016/j.chb.2019.04.008

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