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Robots and autistic children: a review

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ABSTRACT

In accordance with the advancement in robotics and the scholarly literature, the extents of utilizing robots for autistic children are widened and could be a promising method for individual with Autism Spectrum Disorder (ASD) treatments, where the different form of robot (humanoid, non-humanoid, animal-like, toy, and kits) can be employed effectively as a support tool to augment the learning skills and rehabilitate of the individual with Autism Spectrum Disorder (ASD). Thus, the robots were exploited for ASD children in different aspects namely; modelling, teaching, and skills practicing; testing, highlighting and evaluating; providing feedback or encouragement; join Attention; eliciting social behaviours; emotion recognition and expression; imitation; vocalization; turn-taking; and diagnostic. The related literature published recently in journals and conferences is taken into account. In this paper, we review the use of robots that help in the therapy of individuals with Autism Spectrum Disorder (ASD). The articles on using robots for autistic children rehabilitation and education which reported results of experiments on a number of participants were implicated. After looking in digital libraries under this criteria, and excluding non-related, and duplicated studies, 39 studies have been found. The findings were focused mainly on the social communication skills of autistic children and how the extent of the robots mitigate their stereotyped behaviours. Deeper research is required in this area to cover all applications of robotic on autistic children in order to design feasible and low-cost robots that ensure provide high validity.

Keywords: ASD rehabilitation, Autistic children, Autism therapy, Robotic treatment, Social robot

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1. Introduction

The widespread of robots' utilization, especially in the diagnosis and treatment area, open a huge gate for the invention to mitigate the effects of those who are afflicted with serious disabilities. Autism Spectrum Disorders (ASD) considered one of the serious disabilities, where is a neurological disorder that causes difficulties in social communication, social interaction, abnormal behavior, and interests [1][2]. ADS affects about 1 in 68 children, with varies in the disability levels from very mild to severe [3], [4]. Recently, the robots are exploited numerously in different assistive scenarios such as to fulfill various needs of humans and to aid in the rehabilitation of individuals with ASD as well. Robots have been developed in several different aspects and forms to peer-reviewed in autistic children therapy, some of them are dedicated to rehabilitation while the others for treatment and diagnostic.

There is a considerable amount of literature on this area, in the study of Pennisi et al. [5], the authors carried out a systematic review on the optimizing social robots for autism therapy in the period from March 2005 to March 2015. The study tried to provide a clinical perspective by evaluating the feasibility of an optimized robot mediated therapeutic approach in ASD.

Cabibihan et al. [6] conducted a review of the literature on using social robots to assist in the therapy of children with ASD. The study extracted and analyzed the most important experimental data from the previous research in the same area by focusing on particular behaviors and examine the usage of robots individually during the therapy session to achieve these behaviours. Provoost et al. in [7], provide a technological overview base for Embodied Conversational Agents (ECA) applications. In their work, the overview of the technological and clinical possibilities have been embraced base for ECA applications in clinical psychology, by providing information about the activity in this area [7][8].

In this review, we aim to review the use of robots as a social mediator to help individuals with ASD in therapy and education and assess to improve the existing proposed approaches in the same area. This paper is organized as follows: In section 2, the method of screening for the existing literature of "using robots in children with ASD therapy" under the predefined criteria is demonstrated. In section 3, the results of studies that meet the review criteria are presented and discussed in detail. Finally, the conclusion of this study is driven in section 4.

2. Materials and method

This review was concentrated on articles published recently on using robots for autism therapy those include peer reviewed journals, published conferences, which reported clear findings, a certain number of participants, and published in the English language. In the electronic database, we looked up in the Tobic (titles, keywords, and abstracts) of the articles for the keywords autism and robot. From the databases Web of Science (webofknowledge.com), Scopus (scopus.com), and IEEE Xplore (ieeexplore.ieee.org/Xplore) search engines around 100 studies were found. The inclusion criteria that has been applied to that studies collection were as follow:

a) If the study objective/s were on the therapy of children with ASD.
b) If the study were conducted using one or more robots.
c) If the study achieved an experiment or evaluated model on one or more participants.

From the collected studies, all duplicated studies that have been retrieved from more than one library have been excluded. After classification for the studies according to the including criteria and years of publication, a deeply filtering has been performed to exclude non-related studies. The filtering started from the title, the abstract, then the contents of all studies. Eventually, by applying all of the inclusion, exclusion criteria and the contents screening, only 39 studies met all of that.

3. Results and discussion

The screening based on the inclusion and exclusion criteria, and the duplicate's removal, the remained studies N =39. Thus, only these articles were selected to be fully reviewed. The studies date started from 2008 to 2017, Figure 1 depicts the accelerated increase in the number of published articles on using robots to help children with ASD. Table I presents a classification of the identified studies in this paper according to the reference number, year of publication, the used robot/s in every study, the participant's number, the participants' ages, the objective of the study, and the findings.

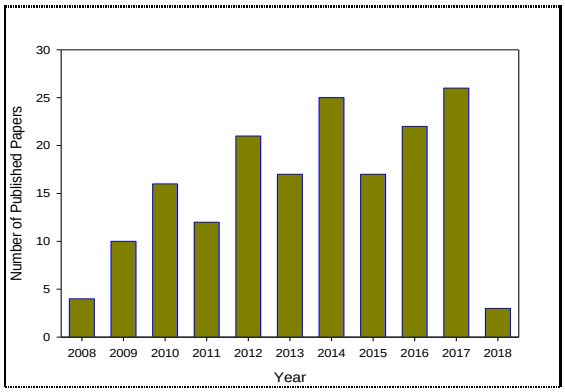

Figure 1. Number of published papers per year

All studies collected in Table I are analyzed according to the targeting objectives, whereas each of which has dedicated to performing a particular task. Therefore, in all studies, the robots are categorized into three main groups:

3.1. Elicit Autistic Children Behaviors

In many studies, the robots are used in rehabilitation and therapy treatment for children with special needs. Humanoid robots are most widely used while the non-humanoid robots (animal-like and toy robots), and robotics kits are used in some other studies.

1) Social Behaviors Elicitation (3 Studies): One of the common uses of robots among treatments for autistic children is eliciting their social behaviors. Three studies were dedicated to eliciting social behaviors using three different robots. In [9], COLOLO robot comprised of automatic feedback and colored lights and vibration was used, therefore the robot increases the eye contact for the children. Another study [10] showed some children don't like some of the robot features. In the last study [11], the children showed a positive response.

2) Imitation (3 Studies): Three studies tested the effect of the two robots (NAO and Darwin-OP) on imitation behaviours. In [12], the positive results have been generated for movement imitation and synchronous speech instruction. The other two studies [13], [14] showed failure in robot imitation test, however, in [13], the positive effects are generated on the social behaviors of children toward a human partner.

3) Joint Attention (6 Studies): Six studies tested the robots on eliciting the join attention. In four studies the results showed that the robots can improve joint attention and engagement time for autistic children. In [15], the robot produces a difference in eye contact and facial expression behaviors. While the results in [16], highlighted that, the robot generated a perturbing effect on children with ASD attention.

4) Turn-taking (3 Studies): Three studies were conducted to test the robot effect, in turn, taking in children with ASD. There are no clear results in the two studies from those three. The third study (Kose-Bagci et al., 2008) reported that the Kaspar Robot enabled more interaction and natural turn talking.

5) Emotion Recognition and Expression (5 studies): Five studies used robots on individuals with ASD to elicit their emotion recognition and expression. In four studies, the findings presented that, the used robots can improve the children's social skills including emotion recognition. Another study (Bonarini et al., 2016) was conducted on NDD children, where the results reported that in all participants, there are no positive effects were presented.

6) Spoken Ability (4 Studies): There are four studies that used five different robots for language improvement. All those studies reported that the robot helps improving children's spoken ability.

Table 1. Classification of identified studies

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
Elicit social behaviors						
[9]	2017	COLOLO	3 ASD	3-6	To examine the social play behaviors of autistic children with the paired robotic devices COLOLO which comprises automatic feedback, and provided by colored lights and vibration	The result showed that color light and vibration increased ball contact and looking at the ball of the therapist. As for automatic feedback, there is no consistent effect on all children.
			3 PDD	5-6		
[10]	2017	PARO	9 ASD	8-19	To evaluate the treatment for children with Autism Spectrum Disorder (ASD) to develop communication skills or mitigate impulsive behaviors or anxiety	Some children don't like some of the robot features, for instance, its big eyes or slight drive noise.
[11]	2016	iRobiQ and CARO	8 ASD	3–5	To test whether the robot_assisted intervention system is feasible to utilize in social skills training for autistic children using human_robot interaction architecture	The children with autism respond positively, in addition to that, a labor-saving effect can be achieved during children's treatment
Imitation						
[13]	2017	NAO	12 ASD	11.7±2.6	To test influence the robot on autistic children for imitation capability or initiated gestures.	The children with an over-reliance on proprioceptive cues and hypo-reactivity to visual cure shown difficulty for robot

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
						imitation more than the other children, where the repeated sessions generate positive effects on social behaviors in all children toward a human partner.
[12]	2016	NAO	5 ASD	>=8	To evaluate the effectiveness of NAO on children with ASD using movement imitation and synchronous speech instruction.	The results showed that the movement imitation and synchronous speech instruction are flexible and convenient for assisting intervention in children (with and without ASD)
[14]	2014	Darwin-OP	2 ASD	8	To develop social skills including interpersonal synchrony and concentration in the autistic children, the robot was used to play music while the children with ASD imitate it.	The children showed failure in imitating the robot.
Joint Attention						
[17]	2016	NAO	12	3-4	To increase engagement time in the institutes	ASD children's concentration time and efficiency in the classroom for long term usage for specific exercises can be increased using these robots.
		Zeno	6	6-7		
		Romibo	29	5-7		
[18]	2017	NAO	5 Healthy	3-7	To examine children level response to a robotic-avatar therapeutic	1- the interaction time and response can be increased, which lead

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
					system that was designed for ASD children's therapy service	to increase the attention time. 2- the progress of interaction can be automated and measured easily.
[15]	2016	Zeno R25	3 ASD	8-13	To improve joint attention, eye contact, and emotion recognition.	Using the robot, differences in eye contact and facial expression behaviors are perceived.
[16]	2017	NAO	1 ASD	17	To reinforce the mental skills of autistic children using EEG and robot to induce joint attention.	The results highlighted that the robot generated a perturbing effect on autistic children's attention.
[19]	2015	CuDDler (A*STAR Singapore)	7 ASD	4 - 5	Using a training protocol comprises CuDDler robot to train children with autism on joint attention skills.	There is an improvement in joint attention skills post-training relative to a pre-training test.
[20]	2009	multi-modal interface include Zino R25	6 ASD	6-13	To improve joint attention, eye contact, and imitation by involving Zino R25 in the multimodal interface based on a multilevel treatment protocol.	The results achieved in autistic children were better than in traditional therapy.
Turn-taking						
[21]	2015	COLOLO	1	6:11	Use the robot to assist the therapist in elicit the child's behavior by engaging the child in the turn_taking activity.	By this robot, the therapist can collect useful information that allows to understand and adapt the activities according to the child's

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
						progress.
[22]	2016	COLOLO	4	4-6	Propose a model using paired devices as a mediator to facilitate turn_taking behaviors between children with ASD and therapists.	The proposed method used to engage children and to measure the social performance of autistic children.
[23]	2008	Kaspar	12	23-32	To facilitate social interaction between the human and humanoid by reinforcement turn_taking and role switching.	By these models, more interaction and natural turn talking are enabled
Emotion recognition and expression						
[24]	2012	AdMoVeo	3	6-7	Using a robot to account the symptoms of ASD utilizing empathic interactions of concern and empathic accuracy in different personalities.	The used robot showed the ability to develop various social skills and complex cognitive.
			4	7-8		
			5	8-9		
[25]	2014	Minimalist InterActor	20 NT and 20 ASD	6-7	Use Minimalist InterActor robot to observe verbal and emotional expressions of autistic and neurotypical children.	The robot that equipped with predictable reactions is able to facilitate autistic children in an expression better than a human
[26]	2017	Monkey	13 ASD	5-11	To elicit social interaction using developed humanoid robotic monkey (Socially Animated Machine (SAM))	SAM can be used as an intervention tool for autistic children to improve their social skills including emotion recognition.
[27]	2016	Teo	11 NDD	6-10	To improve socialization,	Difficult to measure

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
					positive emotions, and self-expression skills in children with ASD	causality relationships. The isolation for all potentially confounding variables that may influence the improvement process is almost impossible to be isolated. In all participated children there are no Some positive effects were presented.
[28]	2017	RoboKind Zeno R50 robot (ZECA)	6 ASD	8-9	To use RoboKind Zeno R50 robot (ZECA) as a mediator with autistic children to promote imitation and recognition of facial expressions	By this system, the robot showed the ability to interact with children with ASD naturally and comfortably especially in emotion recognition and imitation skills
Vocalization						
[29]	2008	AIBO and Kasha	11 ASD	5-8	To examine whether the dog robot can help to promote social interaction skills for autistic children.	Using AIBO robot, the children spoke more words and being more engaged in 1) verbal engagement, 2) reciprocal and authentic interaction behaviors.
[30]	2017	Sphero robot	4 ASD	5.5	Using Sphero robot to develop social and communication skills in children with ASD	Produced an interesting interaction where the children were encouraged to, 1) speak and utter more words, 2) practice friendship with the robot, 3) share feelings and develop more

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
						interaction with parents/therapists.
[31]	2018	NAO	6 ASD	11-15	Using robots to improve social skills by linking voice to gestures.	The autistic children showed fast change effects in communication behavior.
[32]	2016	Minimalistic toy	20 ASD	7-9	Use Minimalistic toy as a tool for children with ASD to analyzing their scenery of speaker/ listener condition	This robot was considered as a neuronal organizer and reorganizer with the potential to improve brain activity
Modeling, teaching, and skill's practicing						
[33]	2017	Ifbot	3 ASD	8-11	Examined the feasibility of collaborative learning between ASD children and a robot.	ASD child communicated with the robot as a human friend and corrected the robot's mistake.
[34]	2017	Puffy	2 ASD	7-9	Designing Puffy to be used as a learning and play tool for children with different forms of NDD.	The subjected children showing education behaviors during the experiment which does not happen very often before.
[35]	2017	ACTROID-F (female)	1	18	To use the robot as an intervenor in therapy and education using taking note system	The result showed stress was decreased effectively
[36]	2016	NAO	6 ASD	12	To teach ASD children gestural comprehension and production using video modeling.	Video modeling by a robot animation is an effective way to teach ASD children the recognize and generate

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
						gestures
[37]	2010	Iromec	5 ASD	6-11	Using Iromec robot to empower the children with ASD to learn a wide range of play styles to improve their social interaction.	All the children were interested in all playing scenarios.
[38]	2006	Ifbot	3 GZ	-	Examine the effects of the robot for collaborative learning in gray zone children.	It found that using the robot in collaborative learning increased the time span for the learning session. In addition, it stimulates the gray zone children to learn efficiently for a longer time.
[39]	2017	NAO	8 ASD	4-10	To use NAO to improve the social skills of autistic children by dance therapy.	The children showed more engagement and motivation
[40]	2016	Lego NXT	3 ASD	12	Uses Lego NXT as Socially Assistive Robotics (SAR), to teach the children with ASD social behavior.	SAR can have a significant impact on breaking stereotypic behavior, avoidance, and rejection pattern
[41]	2017	NAO	1 ASD	8	Design a program to control the NAO robot remotely through a tablet	The program gave the ability to direct therapy sessions with a tablet.
[42]	2015	NAO	6 ASD	8-12	Using a humanoid robot to create and co-design LEGO in autistic children treatment to improve their social skills	Using a robot to create and co-design LEGO gives possibilities for intervention with children for a long time which lead to increase the social

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
						interaction
Provide feedback or encouragement						
[43]	2017	ZECA	15 ASD	1-5	Use ZECA robot as a promoter for ASD children to interact in some education scenarios.	ASD children are able to interact in a comfortable and natural way, thus this system can be used as a promoter in academic and social learning.
[44]	2012	Lego Mindstorms NXT	14 ASD	6-16	To assess the effectiveness of the robot on children with autism disorder, check where the children with ASD can be stimulated to interact and gained learning skills using the robot as a promoter.	There is no pattern can predict either the robot will be used as an interaction promoter or it will not give significant changes to children with ASD.
[45]	2016	NAO	3 ASD	5,6,14	Utilizing NAO as an agent to assist autistic children during therapy sessions using a Tangram puzzle game	The robot assisted the children during the playing time and stimulate their attention towards the game
[46]	2018	-	47 Normal 36 ASD 5 CIMA	5-14	Using a robot as assistive for psychological and therapeutic intervention in the integrative ecosystem	Both children and specialists showed high levels of acceptance.
[47] [46]	2016	TWC soft wearable – social	5 ASD	3-10	Use TWC (embedded social robot) for therapy support and developing social skills in autistic	From the results, the TWC responses are used to increase the engagement time of

Study	Year	Robot	Number of Participants	Age (Y)	Objective	Finding
					children.	the children. Aside from that, the wearable companion is allowed to communicate with children or caregivers and therapists.

3.2. Modeling, Teaching, and Skill's Practicing (10 Studies)

Ten studies were dedicated to improving the social skills in children with ASD by learning and practicing some interaction skills. Six robots were used (NAO, Ifbot, Puffy, ACTRO ID-F, Iromec, and Lego NXT). All studies reported that the robots improve the communication skills of the children in dealing with the robot as a friend, decrease the stress during the playing sessions, improve the educational experiences for autistic children by increasing the engagement and social interaction time span in all playing and education scenarios.

3.3. Promoter (5 studies)

Five studies examined the utilization of robots as a promoter to improve interaction and communication skills in an individual with ASD. The outcome of four studies showed that the robot can assist in practicing specific skills, unlike one study [44] reported that there is no pattern can predict either the robot will be used as promoter or it will not give significant changes to children with ASD.

4. Conclusion

Yet robotic therapy has brought positive outcomes for individuals with ASD. Different robots' models have been utilized, human-like (humanoid), animal-like, and toy robots. All of those robots were used according to their features either as promoter, mediator, analyzer or monitor tool. NAO robot was used in most studies. From this work, we concluded that more studies and efforts in this field are required. It is required to conduct other researches to determine the feasibility and validity of the robots used in autism treatment and therapy.

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