Review on the role of Assistive Technology for the training of individuals with Autism Spectrum Disorders

Christine K. Syriopoulou – Delli

Department of Educational and Social Policy,

University of Macedonia

csyriop@gmail.com

Gkiolnta Eleni

Department of Educational and Social Policy,

University of Macedonia

lls17002@uom.edu.gr

Running Head

Assistive Technology for Children with ASD

Corresponding author:

Christine K. Syriopoulou Delli, Postdoc on Autism Spectrum Disorders, PhD

Assistant Professor, Autism Spectrum Disorders

Department of Educational and Social Policy

University of Macedonia, Thessaloniki

156 Egnatia str.

54336 Thessaloniki

Mobile phone +030 6938704339

csyriop@gmail.com

Compliance with Ethical Standards

FUNDING: This study is self- funded

CONFLICT OF INTEREST: The authors have not received grants. There is no conflict of interest

ETHICAL APPROVAL: All procedures in studies involving human participants were in accordance with the ethical standards of the institutional and / or national research committee and with 1964 Helsinki declaration and its later amendments or comparable ethical standards

INFORMED CONSENT: Informed consent was obtained from all individual participants included in the study

DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST: All authors declare that there is not conflict of interest

Abstract

The use of social robotics could be a very promising method of improving the social skills of children with autism. Many studies have been conducted in this field during the past years, proving that the use of robots as collaborators may have positive effects on the development of social skills for children of the autism spectrum, especially in those areas where they reveal great deficits.

In this literature review, we are attempting to display, organize and evaluate the most important features and results of twelve (12) scientific articles. The analysis of those results is expected to answer our research hypotheses about the effectiveness of robotics in enhancing the social skills of children with autism like joint attention, verbal communication, imitation skills, etc. From the analysis that is resulting from these variables, it is shown that robotic tools have a positive effect and some suggestions for future research are also being provided.

Keywords: autism spectrum disorder, robotics, social robotics, social skills

Introduction

Autism spectrum disorder is a neurodevelopmental disorder that appears in the form of severe difficulties in social communication and interaction and also repetitive behaviors and stereotypical interests. The main cause of autism is a neurobiological malfunction that can not be traced in a specific area of the brain, impeding its normal function (Cho & Ahn, 2016).

To consider that autism is the syndrome that is present, the main symptoms must turn up in a child's early developmental period and impede its daily actions (DSM-V; APA, 2013). Some of the most common symptoms that occur are difficulties in joint attention and cognitive, sensory, motor and emotional functions. Children with autism spectrum disorders also display difficulties in managing their social relationships, understanding other people's feelings, motives, and body language, etc. We are viewing a spectrum of symptoms, so it is possible to come across low functioning or high functioning children.

The verbal and non-verbal skills of children with autism are quite low and in some cases, they don't ever develop a completely functional speech that corresponds to their chronological age. The lack of awareness of other people's way of thinking and presence, in general, is another main feature of autism spectrum disorders alongside with difficulties in social interaction (Quill, 1995).

According to prior epidemiological studies, the occurrence rate of autism was 1:100 children in 2006, 1:88 in 2008 and 1:68 in 2010 (Cho & Ahn, 2016). Autism can be diagnosed in early childhood (Ouss et al., 2014) and early intervention is necessary to minimize the occurrence of symptoms.

Children in the autism spectrum tend to adjust to schedules that include repetitive patterns and activities while their typically developing peers can adjust relatively easily in new conditions. Every child with autism has different abilities and needs, so different personalized programs must be designed for each child separately. In the last decades, many methods for autism treatment have been developed and some of the most common are Applied Behavioral Analysis, the TEACCH Autism Program, the Picture Exchange Communication System (PECS), the MAKATON language program, the SPELL framework, and Sensory Integration Therapy.

Apart from these methods, there is growing progress in Énformation and Communication Technology (ICT) for autism. Assistive technology refers to "an electronic item/equipment, application, or virtual network that is used to intentionally increase, maintain, and/or improve daily living, work/productivity, and recreation/ leisure capabilities of adolescents with autism spectrum disorders" (CSESA Technology

Group 2013). According to researchers, the use of assistive technology can be more beneficial for people with autism than other traditional methods (Bauminger et al., 2007). Assistive technology might cause improvement in several skills of children with autism because the information is now visualized. It also comes across as less "intimidating" because a computer offers stability and does not exhibit emotional transitions in a way that a human partner would.

A widely used means of assistive technology is the electronic computer. The use of computers in Information and communications technology (ICT) is mainly focused on establishing interaction between the user and the computer itself and as a result dampening a child's autistic behaviors. An electronic computer environment provides consistency and predictability compared to human partners, encouraging children with autism to engage more in activities that include its use (Bauminger et al., 2007). According to a research conducted by the Autism Research Centre (ARC) which developed a targeted open-source software called "Transporters", a team of children with autism did manage to recognize facial expressions of others more successfully than a second team of children with autism that didn't use the software (Boucenna et al., 2014).

Virtual reality environments is a computer technology that projects a scene or "world" in which users can immerse themselves. These environments can provide a presentation of educational activities that are simplified and realistic at the same time. Through virtual reality, the environment is simulated in a 3D presentation that takes place in real-time (Parsons & Cobb, 2011). This can be either a 3D presentation of images that is controlled through a joystick or an electronic computer (Mitchell et al., 2017) or a fully immersive environment that requires the use of a headset and a body motion detector. However, the cost of these devices has increased considerably over recent years due to high demand, making them inaccessible for most people.

Many applications have been developed for children with autism that involve virtual reality environments, offering predictable interactions between the children and this type of technology. Furthermore, the use of virtual reality environments has been proven to reduce the symptoms of anxiety among participants (Chaby et al., 2012). This method has been used along with other methods to practice increase joint attention, crossing the road, etc. (Wass & Porayska-Pomsta, 2013). Parsons (Parsons, 2016) attempted to analyze the results of previous studies that involve Virtual Reality Environments in autism treatment programs. It should be noted here that while many studies investigate the effectiveness of Virtual Reality Environments for children with autism, only a few of them managed to display evidence that the newly acquired skills were generalized to other settings.

Video Modelling and Video Self-modeling are two of the most popular methods of Video-based Interventions. Both of these methods make use of videos displaying behaviors that the child with autism must imitate. In Video Modeling, the targeted behavior is executed by others while in Video Self-modeling that behavior is executed by the child itself. Other variations of Video-based Interventions are the Point-of-view Video Modeling, which includes a video recording from the child's point of view, the Video Prompting, where the video is being partially presented to the student, and finally the Self-operated Auditory Prompting, which is a self-managing strategy. It has indeed been proven that all of these methods have introduced significant improvements in the social skills of children with autism spectrum disorders (Bellini & McConnell, 2010).

Software programs for autism is also another method that involves the use of technology for educational and treatment purposes. An example is "Gcompris", a software that consists of activities for children between the ages of 2 and 10. This is an open-source software and its activities mainly focus on naming different colors, shapes, and designs, drawing with the mouse and other. These games allow the child to earn mathematical and linguistic skills at a certain level.

Robotics is a technology field that is linked to designing, developing and studying robotic tools. This field combines elements from other scientific fields, such as computer technology, electronics, and engineering. Robotic science has made a giant step forward and has yielded many benefits in the global industry, in medical science and personal care. Robots can be described as automatic machines that incorporate programmed behavior which is used for replacing the human component when it comes to completing a specific task.

Robots can be categorized based on their form and capabilities in four categories, which are:

•Humanoid robots or androids, which come in a form that is similar to that of a human. A good example is "Nao" by Aldebaran Robotics.

•Industrial robots, which complete tasks and execute commands automatically and without human intervention

•Telerobots, which refers to a specific type of semi-autonomous robots that are being used for telecommunications

•Autonomous robots, which are designed with a built-in artificial intelligence (AI) system to complete tasks and act without receiving commands from humans (Amran et al., 2018).

Based on their functionality, robots can also be categorized as follows:

•Social robots, which can get engaged in social interaction with humans through speech and gestures to a certain extent.

•Assistive robots, which help people with special needs and especially those with motor disabilities

•Service robots, which offer any kind of help a person needs.

A new field of robotic technology has emerged in the past years that is called Socially Assistive Robotics (SAR). Robots that belong to this category are more helpful in establishing social interaction rather than offering other kinds of services. It is important to mention that all Socially Assistive Robots are designed to exhibit emotion and facial expressions. Of course, many factors affect their efficiency, the most important of which is their form and characteristics (Scassellati et al., 2012).

According to research, Socially Assistive Robotics has proven to be of help for people with health issues and also for teachers when used for educational purposes (Mataric, 2014). This type of robot can accommodate people with strokes, Alzheimer's disease, intellectual disabilities and children in the autism spectrum to enhance their social interactions (Feil-Seifer & Mataric, 2009). In the case of autism, Socially Assistive Robotics can aid in social and cognitive deficits that may be present through methodologically designed activities (Cho & Ahn, 2016).

Children with autism exhibit a spectrum of characteristics, such as lack of social skills (speech, joint attention, play skills), stereotypical interests, repetitive behaviors, and others. The main aim of intervention programs for children with autism is the enhancement of social skills and the reduction of stereotypical behaviors. Such treatments might make use of various materials, such as toys or even people familiar with the child, to establish an environment for social behavior manifestation. Many studies prove the effectiveness of social robots in provoking social behaviors in children with autism spectrum disorders (Robins et al., 2005; Scassellati, 2005). Children in the autism spectrum constitute a heterogeneous group of children that exhibit different traits and characteristics, although if someone looks closely they could trace some similarities among them.

The use of robotic technology began to overcome the obstacles that appear in human-to-human interaction, as robots can establish a more predictable and simplified form of communication for children with autism. This way they feel safer and they are more likely to engage in activities designed by the researcher. Furthermore, robotic tools contrary to humans can focus on one different task at a time, making learning simpler and more targeted (Amran et al., 2018).

Several types of robots are suitable for teaching children with autism, each one of which has a distinct form and functions. Despite each robot's appearance, children perceive them as attractive toys which increases the chance of them engaging in activities and interaction (Amran et al., 2018). More specifically, it has been found that most people with autism spectrum disorders exhibit a clear preference for robotic tools than to non robotic toys or even people. Also, they tend to respond faster when a robotic partner provides cues compared to a human partner (Bekele et al., 2013).

Robots for use in autism can be found in various forms and the most common categories are the humanoid, those in the form of an animal or machine-like. It must be noted that robots from these categories are not always commercially available, so some research groups started designing and developing their own robots. This situation has resulted in the appearance of differences in the structure and the results of the interventions (Scassellati et al., 2012).

Á robotic tool is eligible for use in an intervention program if some conditions are met. For example, interacting with the environment and the people around or using cues for social interaction are some of them. According to research, a social robot can be used as a model that indicates social behaviour, as a toy that serves as a "bridge" for communication with others and also as a mediator that facilitates the expression of autistic children' feelings and behaviors that wouldn't be expressed otherwise (Scassellati et al., 2012). Besides, a robot must be equipped with facial features that are similar to that of a human (mouth, eyes, nose, etc.) because they help in establishing joint attention between the child and the robot.

Children with autism have a hard time establishing eye contact with other people but according to research that was conducted with the use of robot "Kaspar", eye contact was increased. A human face appears more intimidating than that of a robot, whose expressions and reactions are far more predictable and limited (Amran, 2018). A study conducted by Ricks & Colton (2010) which compared the effectiveness of humanoid and non-humanoid robots, children with autism managed to maintain and generalize the acquired skills from an intervention program using a humanoid robot. However, those children participated more in applications using non-humanoid robots (Ricks & Colton, 2010).

Another characteristic that a robot must have in order to be eligible for use in autism intervention programs is the ability to move or interact verbally with people. A Socially Assistive Robot needs to be designed with interaction abilities if the researcher is aiming to enhance the social skills of children (Amran, 2018).

Apart from humanoid robots, LEGO robotics has started to gain much popularity in recent years. The most popular model of LEGO robots is "Mindstorms", which consists of an intelligent "brick" computer that controls the whole robot, modular sensors and motors and also LEGO parts that can be used for the mechanical parts' construction. Wainer et al. (2010) incorporated LEGO NXT robots in their experiment with 7 autistic children and the results suggest that robotics generated social behaviors such as increased collaboration among the participants and also positive affect. In addition, this positive affect was manifested in other settings later on (Wainer et al., 2010).

The integration of a robot in an intervention program requires its control on behalf of the researcher. A widely known way to control a robotic tool remotely is the

"Wizard of Oz" technique which allows the user to control the robot from across the room or even from another room without it being perceived by the students. The way to do that is through some device such as a tablet or a smartphone that is connected to the robot's software. This is an easy way to adapt a robot's functions to the specific outline of each intervention (Scassellati et al., 2012).

This review aims to present an evaluation of assistive technology in the training of children with autism. The main object was to display the effectiveness of several socially assistive robots in social skills development based on their features and characteristics.

The review was based on the following research questions:

iAre eye contact and joint attention increased when a robotic tool is being used in the intervention?

iDo children with autism exhibit increased verbal skills towards a robot?

iIs it possible to enhance the imitation skills of children with autism through robot interventions?

iIs robotics an effective tool to enhance the social skills of autistic children compared to human interaction?

iDo children with autism exhibit social behaviors towards a robotic partner?

iCan robots be an effective means of developing the social skills of autistic children towards others?

Methods

The methodology of this study is based on Barbara Kitchenham's guide "Procedures for performing systematic reviews". We attempt to conduct a review based on systematic reviews' principles, which means that our current aim is to present, evaluate and assess studies that have been conducted beforehand and are related to a scientific subject or research question. A systematic review is a secondary type of research that is aiming to evaluate a scientific subject in fair terms based on a reliable methodological system (Kitchenham, 2004).

The first step was to search for articles on platforms such as ResearchGate, Google Scholar, Scopus, PubMed and Science Direct. The keywords we used were "autism", "robot", "robotics" and "asd". Our inclusion criteria were formed to include studies that were conducted between the years 2008-2018.

Results

Our first search yielded 210 results and after merging 16 duplicates, 203 studies were left. It is important to note that the final selection for this review was made according to the research questions that were mentioned earlier.

The eligibility criteria that were formed indicated that all studies that could be included should be relevant to the effectiveness or non-effectiveness of robotics in enhancing the social skills of children with autism. Each study should be primary and include an intervention, experiment or case study applied to children with autism. Also, it is required that each study is providing a detailed presentation of the robotic tool's features.

The next step was to exclude studies whose primary objective was the construction of a robotic tool and the lack of reference to its effectiveness in enhancing social behaviors. Also, studies that didn't present any data, their detailed analysis or the exact age of the participants were excluded, as well as studies that included only preschool autistic children (under 6 years of age). The final selection included 12 studies in total.

INSERT TABLE 1 HERE

In every study that uses a robotic tool as a means for achieving the goals of an intervention, the robot's characteristics constitute an independent variable (Begum et al., 2016). In this review, the independent variable is the robot's form (whether it is humanoid, non-humanoid, in animal form, etc.). Other independent variables are the participants' age, their IQ, their gender and the type of intervention. The independent variables of the 12 selected articles were coded as follows:

INSERT TABLE 2 HERE

All behaviors that are expected to change after the intervention are defined as dependent variables (Begum et al., 2016). The dependent variables that are going to be discussed in this review are the following:

INSERT TABLE 3 HERE

Eye contact

As it is shown in Table 3 of dependent variables most studies investigate eye contact and/or joint attention of children with autism. Among those that are analyzed here, 9 studies use eye contact as a dependent variable and investigate whether the use of a robotic tool increases its frequency.

In the study by Pop et al. (2014) eye contact was defined as the gaze orientation of the child towards the play partner's upper body area, meaning the eyes surrounding area for more than two seconds. Two groups of children were formed and one of them participated in the experiment twice. Specifically, the first time all play activities were performed with a human partner and the second time with the robot Probo.

Results showed no significant differences between the two groups initially but with a later analysis that was made separately for each subject, some differences in eye contact appearance were found for the two types of interventions. In the robotic partner intervention eye contact was increased according to Cohen's d (d=3.59) compared to the human partner part of the intervention (d=1.01) (Pop et al., 2014).

Conti et al. (2015) implemented an imitation game of Nao robot's moves and actions in their intervention. They found that eye contact that was oriented towards the robot had a duration of 38% over the whole experiment for the first subject, 54% for the second and 84% for the third subject. But what is interesting is that the children directed their gaze more towards the experimenter after they were informed that he was operating the robot.

Costa et al. (2015) found that eye contact towards the robot Kaspar had a longer duration (>47.3% of the experiment's total duration) compared to eye contact towards the human partner or other directions (27.26% - 39.74%). Furthermore, eye contact towards the human partner seemed to increase five times more at the final phase of the intervention compared to the initial duration (Costa et al., 2015). In a previous study by the same authors, eye contact towards the robot Kaspar, the experimenter, and other directions were measured and the participants formed two groups (high functioning and low functioning children). Two measurements were recorded, one for each phase of the experiment, and the children's gaze towards Kaspar had a longer duration (75.04% and 51.01% of the first and last phase's duration respectively).

A decrease in eye contact towards the robot appears in the last phase, where the child's attention is directed more to the experimenter (4.29% and 16.01% in the first and last phase respectively). According to a paired sample t-test which was applied with the

SPSS software, significant differences between group A and group B were found in the first and last phases ($p= .048$). Also, eye contact towards the experimenter was increasing while decreasing towards Kaspar (Costa et al., 2013).

In the study by Hanafiah et al. (2012) the student maintains his eye contact towards the robot Nao, but he doesn't direct his gaze towards his human partner (Hanafiah et al., 2012). But Wainer et al. (2014) examined the occurrence of social behaviours through collaborative play that had to be executed dyadically (a group of two children) or triadically (two children and the robot Kaspar) and discovered that children directed their gaze more towards one another when Kaspar was acting as a partner in the game. Also, this type of eye contact was increasing as the experiment went on. Furthermore, after triadic interaction was introduced, children made more alterations of their eye contact between the game and their partner (i.e. the other child) (Wainer et al., 2014).

Verbal communication

Pop et al. (2014) measured the occurrence of verbal initiations made by 11 autistic children. The percentage of spontaneous utterances during collaborative play with the presence of the human partner didn't have any statistically significant differences with the presence of the robot Probo in the role of a partner initially ($U = 7.00$, $Z = -1.47$, $p = .140$). After comparing the results of the two groups it was found that 73% of the participants from the group that didn't include the robot had poorer performance in verbal initiations compared to the group that worked with the robot Probo. Another analysis was made for each subject separately and no statistically significant difference was found between baseline and intervention ($Z = -.36$, $p = .715$ for the human partner intervention and $Z = -.67$, $p = .500$ for the robot intervention) (Pop et al., 2014).

Important data is presented by Huskens et al. (2013) using the robot Nao and measuring the number of self-initiated questions in children with autism. Self-initiated questions are considered to be a form of verbal communication and according to the analysis, intervention phases with or without the robot Nao were both successful in self-initiated question asking. There must be noted that the whole experiment was based on the principles of Applied Behavioral Analysis and its effectiveness has been proven experimentally beforehand (Koegel et al., 1998; Koegel et al., 2003; Koegel et al., 2010). It is also explained that the students' scores were already high even at the beginning of the intervention (Huskens et al., 2013).

Kim et al. (2013) investigated the manifestation of the social skills of children with autism with the use of the robot Pleo or without it. Specifically, the researchers compared the use of Pleo, human-to-human interaction and the use of a tablet application concerning their effectiveness in evoking social behaviors. The data analysis was made with a one-tailed paired t-test and was found that participants produced more speech during robot interactions ($M= 43.0$, $SD= 19.4$) as compared to human partner interactions ($M= 36.8$, $SD=19.2$, $t(23) = 1.97$, $p< 0.05$). Also, both ways resulted in more speech compared to the use of a tablet application ($M= 25.2$, $SD= 13.4$). It is worth mentioning that verbal communication was increased towards the human partner when the robot was used.

Severson et al. (2008) compared the interaction of 11 autistic children with the robot dog Aibo and a mechanical toy dog (which wasn't robotic). Results showed that verbal communication with the robot was increased ($M = 2.73$ words per minute, $SD = 3.05$) compared to verbal communication produced when using the mechanical toy dog ($M = 1.07$ words per minute, $SD = 1.62$), $Z = -2.073$, $p = .038$. On the contrary, Wainer et al. (2014) predicted that children would communicate verbally more with the robot Kaspar, but the results didn't confirm their hypothesis, as verbal communication levels were the same on both cases of using and not using the robot (Wainer et al., 2014).

Imitation

Imitation skills enhancement of children with autism through robotic technology is being investigated in 2 of the studies that have been used in this review. Conti et al. (2015) measured the number of imitations or responses of robot Nao's movements that were made by students with autism after the appropriate prompts were given. The first student, although avoiding new situations, showed an interest in the robotic tool and managed to imitate some moves. The second student didn't manage to mimic the robot's movements and the third student was the more successful in mimicking and interacting with the robot Nao. It is important to note here that the second autistic student was diagnosed with severe intellectual disability and was lacking motivation after failing to imitate the robot (Conti et al., 2015).

In the study by Costa et al. (2015) participants were expected to imitate a choreography game which was firstly executed by Kaspar. Even though results were not encouraging at first, the children's imitation scores were increasing as the experiment went on (Costa et al., 2015).

Proximity/Touch

Conti et al. (2015) examined the number of touches that were directed towards the robot Nao and they were not as frequent as other forms of social interaction. For example, the first student touched the robot for 11% and both the second and third students for 3% of the total amount of time (Conti et al., 2015). Costa et al. (2015) exhibited more detailed results about the amount and the quality of touching that is directed towards the robot or the human partner. The robot Kaspar is equipped with touch sensors that allow the researcher to measure the amount and the quality of touches more easily. The results showed differences regarding the intensity of touches toward Kaspar and the human partner (÷2 (6, N = 1432) = 18.34, $p < 0.05$, and ÷2 (6, N = 394)

= 21.49, $p < 0.05$ respectively). The number of mild touches towards Kaspar was 8.5 times larger than the number of harsh touches and regarding the human partner, the number of mild touches was 23.6 times larger than the number of harsh touches.

What is more interesting is that students exhibited more spontaneous touches with the presence of Kaspar (10.3 times more frequent than touches after prompt). After some prompts were provided, touch towards the robotic partner was, in fact, more mild, indicating that robotic technology can aid in directing autistic children towards using touch as an appropriate way of communication (Costa et al., 2015).

Play skills

Many researchers use symbolic play to assess the skills of children with autism and in some cases, they integrate robotic technology in intervention programs to enhance their play skills. According to Pop et al. (2014) children that participated in the study engaged more in collaborative play when the robotic partner was present compared to the human partner ($U=1.00$, $Z = -2.55$, $p = .011$ for the intervention phase). As it was shown from the results, there was a statistically significant difference between the two groups of children. Engagement in functional play wasn't increased with the presence of the robot Aibo but participants directed their play more towards the robot than towards the human partner. In addition, they were more willing to interact with the robot and participate in activities that included the robot with a statistically significant difference between the two groups ($U = 4.00$, $Z = 2.08$, $p = .037$ for the intervention phase) (Pop et al., 2014).

Although the robot Aibo had similar features with the mechanical toy dog used by Severson et al. (2008) children engaged more in play when Aibo had the role of the play partner. They even exhibited more social skills such as unprompted speech, eye contact, etc. (Severson et al., 2008). Wainer et al. (2014) didn't confirm their initial hypothesis that children would engage more in collaborative play with triadic interaction (child-robot-child) compared to dyadic interaction (child-to-child). There were no statistically significant differences regarding how much the students engaged in play after the intervention with the robot Kaspar. But even though children had difficulties in focusing their attention, taking turns and collaborating with others, they all managed to engage in collaborative play for quite some time with the robot (Wainer et al., 2014).

Stereotypical Behavior

The number of stereotypical behaviors is measured in frequency by Pop et al. (2014). The results showed that when using the robot Probo, children had less stereotypical behaviors compared to play activities with the human partner. A statistically significant difference was recorded between the two groups ($U = 4.00$, $Z = -2.05$, $p = .040$) (Pop et al., 2014).

Hanafiah et al. (2012) compared the percentage of stereotypical behavior that was expressed by the participant during the experiment compared to its presence in the classroom. The student K expressed stereotypical behaviors for only 2.5% of the total duration of the intervention with Nao and in the classroom this rate was 25%, indicating a major difference (Hanafiah et al., 2012). Positive results also come from the study by Severson et al. (2008), where the percentage of stereotypical behaviors was .75 per minute with the robot Aibo and 1.1 per minute with the mechanical toy dog. After the Wilcoxon Signed Ranks Test was used to compare the results, a statistically significant difference was found between the two types of intervention ($Z = -1.84$, $p = .066$) (Severson et al., 2008).

Yussof et al. (2013) use a research hypothesis that children with autism exhibit less stereotypical behaviors when a robotic partner is present. The researchers measured the participants' stereotypical behaviors using a list called "The Gilliam Autism Rating

Scale" (GARS-2). The hypothesis that was mentioned above was confirmed by the results since student 1 exhibited only 6% of the list's behaviors and student 2 exhibited 17% of them. These results seem encouraging since the measurements were made the first time the participants had contact with the robot Nao (Yussof et al., 2013).

Engagement & Positive Affect

The engagement was taken into account by Kim et al. (2012) by examining one group of typically developing children and one group with autistic children. Each group had to interact with the robot Pleo during activities and both engagements with the robot and other people were measured. A Likert scale and an inter-rater reliability between two observers was used and the results indicated that the group of autistic children exhibited no difficulties engaging in activities with the robot as compared to the typically developing group (TD: $M=4.36$, $SD=.50$; ASD: $M=4.27$, $SD=.62$; $t(27)=.39$). In addition, children with autism spent more time of free play with Pleo in comparison with the typically developing group (TD: $M=207s$, $SD=49s$; ASD: $M=307s$, $SD=137s$; $t(20.3)=2.7$, $p=.02$, Cohen's $d=0.97$). These findings support the researcher's initial hypothesis that children with autism engage in play with a robotic partner as much as their typically developing peers do. So it seems that robotic tool integration in class might be a pleasant way of teaching children with autism, making them more motivated in learning new things and interacting with others (Kim et al., 2012).

Wainer et al. (2014) also managed to support their research hypothesis, meaning that children with autism would interact more with their partner if the robotic tool worked also as a partner (triadic interaction). Results showed that children with autism manifested higher rates of social interaction during the experiment than in the classroom (Wainer et al., 2014).

Although most studies indicate that children and robots interact positively, Feil-Seifer (2011) support a different opinion. The researchers used a humanoid robot named "Bandit" with 8 children with autism, each one accompanied by a parent. The study aimed to record the quality of interaction between the robot and the child in free play activity with the presence of a familiar face. Half of the participants (n=4) exhibited positive affect towards the robotic partner and tried to approach it with social behavior and the other half seemed to have a negative interaction with it. Therefore results were categorized into two groups and the first group (positive reaction) spent 78% of the session interacting with Bandit, 3% staying close to the parent and 11% hiding against the wall, with robot avoidance rate being 0%. The second group (negative reaction) spent 36% of the session interacting with the robot, 2.6% close to the parent, 20% avoiding the robot and 38% hiding against the wall (Feil-Seifer, 2011).

Conclusions

In this review, we attempted to present and elaborate on the benefits of using technology and particularly Socially Assistive Robots in autism therapy. Although every robotic platform has its unique features and abilities, scientific research has proven that they can aid in enhancing and developing the social skills of children with autism. Those skills were categorized in Table and were coded as variables to facilitate the outcome of conclusions.

Many of the studies that were used for this review present small samples, so the following conclusions can work as hypotheses for future investigation. The most important information comes from the analysis of those studies that integrated bigger samples and systematic measurements.

Eye contact is an ability that is poor for children with autism, so a robotic tool might aid in enhancing it. Pop et al. (2014) support this hypothesis, as their study showed that eye contact was increased when a robotic partner Probo was used. Other studies prove Probo's effectiveness in this part, such as the one by Simut et al. (2015). In this study, the quality of interaction of 35 autistic children was measured through play activities with Probo and the therapist separately. No differences in interaction quality were indicated for the two types of intervention except for eye contact, which was increased with the presence of the robot.

Nao robot is one of the most popular robotic platforms in autism research. Conti et al. (2015) noted that eye contact was directed to Nao for a large percentage of the experiment's duration. Hanafiah et al. (2012) also used Nao and noticed that the student made eye contact with Nao, but not with the therapist. According to the researchers, this was due to the lights that were flashing from the robot's eyes. In another study by Tapus et al. (2012) the effect that Nao robot had wasn't clearly positive because half of the participants (2 out of 4) exhibited increased eye contact. There must be noted, though, that the study's small sample is setting some limitations.

Other studies that were included (Costa et al., 2015; Costa et al., 2013; Wainer et al., 2014) commented on Kaspar's abilities in eliciting eye contact. Costa et al. (2013) mentioned that eye contact towards the therapist was gradually increasing, so this could be very promising for Kaspar's potentials in this part. Although most researchers agree that eye contact is maintained between the child and the therapist or the robot itself, some others claim that robots induce negative effects, as they distract children from the current activity (Anzalone et al., 2014; Bekele et al., 2013; Warren et al., 2013).

A useful future practice might be to compare the effectiveness of different robotic platforms to several groups of children. The focus of a child's gaze towards a robot doesn't generate social behavior on its own, but it's a way of teaching to autistic children how to maintain this contact when necessary. When the student is able to maintain it, then the robotic partner should be replaced gradually by a human partner for generalization of the acquired skill.

Verbal communication is another social skill that is deficient in many autistic children, and Pop et al. (2014) didn't notice a major improvement in verbal initiations as the sessions of the experiment went on with Probo. Positive results also derived from the study by Severson et al. (2008) when comparing speech towards robot Aibo and a mechanical toy. As expected, verbal communication was increased in the first case. Some researchers assume that the younger the age of the child, the better the results that come up (Tartarisco et al., 2015). This claim cannot be yet confirmed but it could be investigated in future research.

Imitation is mentioned in 2 articles that were used for this review, and the one by Costa et al. (2015) using the robot Kaspar had more reliable results. According to this, imitation attempts were increasing as the experiment went on. Although most studies are measuring the imitations of facial expressions, this study only measured the child's imitations of the robot's body movements. To claim if a socially assistive robot is suitable for stimulating imitation skills, studies' focus should be on developing activities for imitation of facial expressions on large groups of children with autism. Some examples of robots that can be used for this purpose are the robot "Face" and the robot "Zeno".

Touch has an important role in shaping a child's social skills during its development. Tactile interaction allows the child to be aware of its own existence and the presence of others. It has been observed that some children with autism have a hypersensitivity to touch and tend to avoid it or even exhibit signs of panic. This behavior can be triggered in case someone or some specific material touches the child. Many robots are developed to elicit tactile interaction and measure the quality of the touch (frequency, intensity, etc.).

Costa et al. (2015) used Kaspar, a robot that is equipped with touch sensors and was able to evaluate the quality of tactile interactions. Apart from being able to give the right prompts to the participants, researchers also noticed that spontaneous touching was more frequent when Kaspar was present in the experiment. Nao robot is equipped with motion detectors, but Kaspar can detect the quality of touching and respond accordingly. Also, the frequency of touching a robot is affected by the features of the robot itself. For example, Kaspar is covered with a soft fabric material which makes it look like a toy doll, compared to Nao which has a plastic cover.

Play is a fundamental activity in a child's life and its absence might hinder its healthy development. According to the World Health Organization (WHO, 2001) play is an integral part of a child's life when its quality is evaluated. Like we mentioned earlier, children with autism have difficulties engaging in the collaborative and symbolic game and end up playing alone, without the involvement of peers. Most studies that use robotic tools emphasize on the collaborative play since this type of play is the most demanding in terms of social interaction. Results from the studies with the robot Probo and the robot Aibo are positive except for one research with the robot Kaspar. In this experiment, all of the participants (6 children with autism) engaged more in collaborative play in dyadic than in triadic interactions.

Patterns of repetitive behavior and adherence to routines are some of the most common characteristics in autism spectrum disorder. Positive results regarding the reduction of stereotypical behaviors are mentioned in 4 studies that were used in this review. For more reliable results researchers could potentially use devices such as motion sensors that detect and record the students' movements. Also, it would be very useful to compare the frequency of these behaviors during and after intervention in different contexts.

Engagement and positive affect were variables that were also described and both terms are referring to the sense of content that a child is feeling when interacting with a robot. Positive affect is a factor that reinforces the possibility of a robotic tool's success. Especially when social skills development is concerned, children with autism are more likely to engage in interaction with a robotic partner if it is enjoyable.

Studies like the one by Kim et al. (2012) include larger samples, in this case, it consisted of 18 autistic students. Researchers described engagement as "positive affect" and compared a group of autistic children with a group of typically developing children. In general, both groups performed the same but autistic children spent more time on free play with the robot, a fact that can be easily translated into positive affect. Wainer et al. (2014) employed a different approach as they compared the engagement of autistic children in the classroom using the robot Kaspar in a triadic interaction.

Although most studies don't mainly examine engagement and positive affect of the participants, Feil-Seifer (2011) focused on this behavior primarily. Half of the children that participated in the experiment showed positive affect after interacting with the humanoid robot Bandit, whereas the other half exhibited signs of discomfort. It is really important to mention, though, that Bandit is a humanoid robot that hasn't been tested by many research groups and on different students with autism yet. It is a robotic platform that has been developed by the same research group that performed the experiment and its effects on different groups of children have not been reported. On the other hand, Kaspar and Pleo are two popular robots that have been used enough times to bring on reliable data. As mentioned in the results, no signs of discomfort or anxiety were reported during experiments.

At this point, we are going to discuss whether our research hypotheses were confirmed by the literature. The first question was about eye contact and joint attention being increased when a robotic tool is used in the intervention. Results show that robotic tools can cause development in eye contact for children with autism and might also help in maintaining it. Although most robotic platforms are different from one another, they all can attract a child's interest and urge them to maintain eye contact. This comes to no surprise as a robot is perceived as an attractive and interesting toy. Also, joint attention is another aspect of social skills that is deficient to autistic children and robotic partners seem to aid in its development, as most of them are designed to give prompts and direct a child's gaze.

The second question is about social robots increasing verbal skills of children with autism. The majority of studies show that socially assistive robots might cause an increase in verbal skills of children in the autism spectrum compared to interventions that are performed only by a person. Only one research showed no evidence of increasing verbal skills with the robot Kaspar, but other forms of social communication were increased after interacting with the robot.

The third research question is about imitation skills and whether they can be developed through robot interaction. Two studies were relevant to this question with both positive and negative results. The first study with robot Kaspar showed positive results for imitation skills as they were developing over time, but the second research didn't yield as positive results with the robot Nao. Also, what is not discussed is the imitation of the robot's facial expressions which correspond to certain emotions. Those two studies that were included in this review were about imitating body moves by a small number of autistic children, which doesn't provide us clear evidence.

The fourth and fifth questions can be answered together as they are about the manifestation of social behavior towards robotic partners and their effectiveness as compared to human interaction. As mentioned earlier, most studies have proven that robotic technology can help autistic children develop their social skills through repeated exposure. In addition, the contentment that participants found in interacting with the robot in most cases are encouraging the researcher or the teacher to further use this method.

Some researchers found out that children with autism had increased verbal communication with their human partner when a robot was present. Also, during the collaborative play of two children with autism and Kaspar, not only did they show increased eye contact towards the robot, but they also directed their gaze towards one another more. So, the sixth research question is answered and our hypothesis that a robotic platform can work as a medium for social interaction is confirmed. Robots appear to be more predictable and stable to their reactions compared to humans, bridging the gap for communication between autistic children and those around them.

Since most studies base their conclusions on the success of the robot in enhancing social skills and communication, very few are those that focus on the maintenance of these abilities outside the clinical setting. That being said, it is very important for researchers to investigate whether the newly acquired skills are being generalized to the child's everyday life as a robotic intervention shouldn't only work in a clinical setting. Social skills integration in everyday routines is an important goal that should also be set by researchers and therapists.

In order to consider an intervention successful, useful information must be given to future researchers in a way that they can reproduce it at a subsequent time. Usually, more weight is given in describing the goals, the participants' characteristics and the results of intervention with the absence of an elaborate description of the stages of the experiment.

Of particular interest would be to examine the effectiveness of a robotic intervention to autistic children of different age groups. Participants from the studies that were used for this review were between the ages of 4 to 14, meaning that most of them were of school age. Some researchers claim that robotics should be introduced to children with autism as an educational practice from an early age to yield better results in the development of verbal communication with others, but the exact age is not determined.

All activities that are designed by therapists or researchers for robotic therapy must be addressed to the group of children that are going to participate in the experiment. This means that each program must be suitable for the child's age, intellectual level, abilities, etc. Valuable data could turn up about the effectiveness of an intervention if those characteristics were set as variables. Heterogeneity between children is very common in autism spectrum disorders and the unique characteristics of one child could either hinder or reinforce the success of an intervention program.

Robotics can work alongside with the therapist or the teacher of an autistic child as a valuable partner for evaluating, designing and implementing interventions. However, a socially assistive robot cannot replace a therapist for many reasons. Firstly, robots are considered to be delicate machines that require operation by humans. A robot's autonomy level is affecting considerably its abilities and limitations, but the presence of a human operator is necessary, especially when used for therapy or educational purposes. Also, without this presence, it is nearly impossible for a child to convey its social skills to humans and there is a risk of failure in the intervention itself.

The positive effects of robotic therapy in enhancing the social skills of children with autism is proved by many studies until today. Research that is carried out in different contexts and by different research teams is published more and more over the past years. Even though we know already that predictable reactions, simpler cues and the attractive appearance of robots might cause the appearance of social behaviors, it is also important to investigate the link between those two, as it may bring future directions for research.

Limitations

In this review, we attempted to answer some research questions about the effectiveness of socially assistive robotics in enhancing the social skills of children with autism. While most questions were answered positively, some others remain unanswered. According to the criteria that were set 12 studies were included, but future researchers could include even more in their reviews in order to produce more accurate conclusions. Furthermore, it is suggested that studies with larger samples that are both qualitative and quantitative in their analysis are included, in a way that makes it even easier to present the results.

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Amran, N.A.B., Gunasekaran, S.S., Mahmoud, M.A. (2018). Investigating the factors that influence the efficiency of using robots as social skills therapy for children with autism spectrum disorders (ASD). *Journal of Fundamental and Applied Sciences,* 10(6S), 1779-1792.

Anzalone, S.M., Tilmont, E., Boucenna, S., Xavier, J., Jouen, A.L., Bodeau, N., et al. (2014). How children with autism spectrum disorder behave and explore the 4dimensional (spatial 3D+ time) environment during a joint attention induction task with a robot. *Research in Autism Spectrum Disorders*, 8, 814–826. doi: 10.1016/j.rasd.2014.03.002.

Bauminger, N., Gal, E., Goren-Bar, D. (2007). Enhancing social communication in high functioning children with autism through a colocated interface. *6th International Workshop on Social Intelligence Design.*

Bekele, E., Crittendon, J.A., Swanson, A., Sarkar, N., & Warren, Z.E. (2013). Pilot clinical application of an adaptive robotic system for young children with autism. *Autism,* 18, 598– 608. doi: 10.1177/1362361313479454.

Bekele, E.T., Lahiri, U., Swanson, A.R., Crittendon, J. A., Warren, Z.E., & Sarkar, N. (2013). A Step Towards Developing Adaptive Robot-Mediated Intervention Architecture (ARIA) for Children With Autism. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*,21(2), 289-299. doi:10.1109/tnsre.2012.2230188.

Bellini, S., McConnell, L. (2010). Strength-based educational programming for students with autism spectrum disorders: A case for video modeling. *Preventing School Failure*, 54, 220– 227.

Boucenna, S., Narzisi, A., Tilmont, E., Muratori, F., Pioggia, G., Cohen, D., & Chetouani, M. (2014). Interactive Technologies for Autistic Children: A Review. *Cognitive Computation,* 6(4), 722-740. doi:10.1007/s12559-014-9276-x.

Chaby, L., Chetouani, M., Plaza, M., & Cohen, D. (2012). Exploring Multimodal Social-Emotional Behaviors in Autism Spectrum Disorders: An Interface between Social Signal Processing and Psychopathology. *2012 International Conference on Privacy, Security, Risk and Trust and 2012 International Conference on Social Computing.* doi:10.1109/socialcom-passat.2012.111.

Cho, S.J., & Ahn, D.H. (2016). Socially Assistive Robotics in Autism Spectrum Disorder. *Hanyang Medical Reviews,* 36(1), 17. doi: 10.7599/hmr.2016.36.1.17.

Conti, D., Nuovo, S.D., Buono, S., Trubia, G., & Nuovo, A.D. (2015). Use of robotics to stimulate imitation in children with Autism Spectrum Disorder: A pilot study in a clinical setting. *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN).* doi:10.1109/roman.2015.7333589.

Costa, S., Lehmann, H., Dautenhahn, K., Robins, B., & Soares, F. (2015). Using a Humanoid Robot to Elicit Body Awareness and Appropriate Physical Interaction in Children with Autism. *International Journal of Social Robotics,* 7(2), 265-278. doi:10.1007/s12369-014-0250-2.

Costa, S., Lehmann, H., Robins, B., Dautenhahn, K., & Soares, F. (2013). "Where is Your Nose?" - Developing Body Awareness Skills Among Children With Autism Using a Humanoid Robot. ACHI 2013, *The Sixth International Conference on Advances in Computer-Human Interactions,* (January 2016), 117–122. Retrieved from https://www.researchgate.net/publication/235350482.

CSESA Technology Group. (2013). *Definition of technology for adolescents with Autism Spectrum Disorders.* Chapel Hill, NC: Center on Secondary Education for Students with Autism Spectrum Disorder.

Feil-Seifer, D., & Mataric, M. (2011). Automated detection and classification of positive vs. negative robot interactions with children with autism using distance-based features, *323*. https://doi.org/10.1145/1957656.1957785.

Feil-Seifer, D., & Matariæ, M. (2009). Toward Socially Assistive Robotics for Augmenting Interventions for Children with Autism Spectrum Disorders. *Experimental Robotics - Springer Tracts in Advanced Robotics,* 54(July), 201-210–210. https://doi.org/10.1007/978-3-642-00196-3_24.

Hanafiah, F.A., Zahari, N.I., Shamsuddin, S., Yussof, H., Ismail, L.I., & Mohamed, S. (2012). Initial Response in HRI- a Case Study on Evaluation of Child with Autism Spectrum Disorders Interacting with a Humanoid Robot NAO. *Procedia Engineering*, 41(Iris), 1448–1455. https://doi.org/10.1016/j.proeng.2012.07.334.

Huskens, B., Verschuur, R., Gillesen, J., Didden, R., & Barakova, E. (2013). Promoting question-asking in school-aged children with autism spectrum disorders:

Effectiveness of a robot intervention compared to a human-trainer intervention. *Developmental Neurorehabilitation,* 16(5), 345–356. https://doi.org/10.3109/17518423.2012.739212.

Kim, E.S., Berkovits, L.D., Bernier, E.P., Leyzberg, D., Shic, F., Paul, R., & Scassellati, B. (2013). Social robots as embedded reinforcers of social behavior in children with autism. *Journal of Autism and Developmental Disorders*, 43(5), 1038–1049. https://doi.org/10.1007/s10803-012-1645-2.

Kim, E., Paul, R., Shic, F., & Scassellati, B. (2012). Bridging the Research Gap: Making HRI Useful to Individuals with Autism. *Journal of Human-Robot Interaction*, 1(1), 26– 54. https://doi.org/10.5898/jhri.1.1.kim.

Kitchenham, B. (2004). *Procedures for performing systematic reviews.* Keele University,UK and National ICT Australia, 33, 28. https://doi.org/10.1.1.122.3308.

Mataric, M. (2014). Socially Assistive Robotics: Human-Robot Interaction Methods for Creating Robots that Care. *Proceedings of the 2014 ACM/IEEE International Conference on Human-Robot Interaction* - HRI '14, 333–333.

Mitchell, P., Parsons, S., and Leonard, A. (2017). Using virtual environments for teaching social understanding to 6 adolescents with autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, 37(3): 589–600.

Ouss, L., Saint-Georges, C., Robel, L., Bodeau, N., Laznik, M.C., Crespin, G.C., Chetouani, M., Bursztejn, C., Golse, B., Nabbout, R., et al. (2014). Infant's engagement and emotion as predictors of autism or intellectual disability in west syndrome. *European child & adolescent psychiatry,* 23, 143-149.

Parsons, S. (2016). Authenticity in Virtual Reality for assessment and intervention in autism: A conceptual review. *Educ. Res. Rev.*, 19, 138–157.

Parsons, S., Cobb, S. (2011). State-of-the-art of virtual reality technologies for children on the autism spectrum. *European Journal of Special Needs Education,* 26(3), 355–366. DOI: 10.1080/08856257.2011.593831.

Pop, C.A., Pintea, S., Vanderborght, B., & David, D.O. (2014). Enhancing play skills, engagement and social skills in a play task in ASD children by using robot-based interventions. A pilot study. *Interaction Studies Interaction Studies Social Behaviour and Communication in Biological and Artificial Systems*, 15(2), 292-320. doi:10.1075/is.15.2.14pop.

Quill, A.K. (1995). *Teaching Children with Autism: Strategies to Enhance Communication and Socialization.* Delmar Publishers Inc.

Ricks, D.J., & Colton, M.B. (2010). Trends and considerations in robot-assisted autism therapy. *Robotics and Automation (ICRA), IEEE (Institute of Electrical and Electronics Engineers) International Conference* (pp. 4354–4359).

Robins, B., Dautenhahn, K., Boekhorst, R., Billard, A. (2005). Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills? *Universal Access in the Information Society,* 4(2), 105–120.

Scassellati, B., Admoni, H., Mataric, M. (2012). Robots for Use in Autism Research. *Annual Review of Biomedical Engineering*, 14, 275–94.

Scassellati, B. (2005). Quantitative metrics of social response for autism diagnosis. *IEEE International Workshop on Robots and Human Interactive Communication (ROMAN),* pp. 585–590.

Severson, R.L., Stanton, C.M., Gill, B.T., Ruckert, J.H., & Kahn Jr., P.H. (2008). Robotic animals might aid in the social development of children with autism, 271. https://doi.org/10.1145/1349822.1349858.

Simut, R.E., Vanderfaeillie, J., Peca, A., Perre, G.V., & Vanderborght, B. (2015). 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. doi:10.1007/s10803-015-2556-9.

Tapus, A., Peca, A., Aly, A., Pop, C., Jisa, L., Pintea, S., . . . David, D.O. (2012). Children with autism social engagement in interaction with Nao, an imitative robot: A series of single case experiments. *Interaction Studies, Social Behaviour and Communication in Biological and Artificial Systems*, 13(3), 315-347. doi:10.1075/is.13.3.01tap.

Tartarisco, G., Pennisi, P., Pioggia, G., Gangemi, S., Ruta, L., Billeci, L., & Tonacci, A. (2015). Autism and social robotics: A systematic review. *Autism Research*, 9(2), 165–183. https://doi.org/10.1002/aur.1527.

Wainer, J., Robins, B., Amirabdollahian, F., & Dautenhahn, K. (2014). Using the humanoid robot KASPAR to autonomously play triadic games and facilitate collaborative play among children with autism. *IEEE Transactions on Autonomous Mental Development*, 6(3), 183–199. https://doi.org/10.1109/TAMD.2014.2303116.

Wainer, J., Ferrari, E., Dautenhahn, K., & Robins, B. (2010). The effectiveness of using a robotics class to foster collaboration among groups of children with autism in an exploratory study. *Personal and Ubiquitous Computing*, *14*(5), 445–455. https://doi.org/10.1007/s00779-009-0266-z.

Warren, Z.E., Zheng, Z., Swanson, A.R., Bekele, E., Zhang, L., Crittendon, J.A., & Sarkar, N. (2013). Can robotic interaction improve joint attention skills? *Journal of Autism Development Disorder*, 1–9.

Wass, S.V., & Porayska-Pomsta, K. (2013). The uses of cognitive training technologies in the treatment of autism spectrum disorders. *Autism*, 18(8), 851-871. doi:10.1177/1362361313499827.

WHO (2001) *International classification of functioning, disability and health.* World Health Organization, Geneva.

Yussof, H., Miskam, M.A., Malik, N.A., Hamid, M.A.C., Shamsuddin, S., & Basir, S.N. (2013). Study on Social Interaction between Children with Autism and Humanoid Robot NAO. *Applied Mechanics and Materials*, 393, 573–578. https://doi.org/10.4028/www.scientific.net/amm.393.573.