The Impact of Assistive Technology on Autism Spectrum Disorder: A Systematic Review

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Abstract

The purpose of this research was to review the assistive technology (AT) specific assessment models and instruments that have been developed for children with Autism Spectrum Disorder (ASD) in order to provide an overview of the strategies to be employed in rehabilitation and education. Three electronic databases were searched for peer-reviewed studies investigating children with Autism Spectrum Disorder (ASD) and the use of assistive technology to assist with speech difficulties, little social interaction, and poor motor skills. Relevant studies were independently reviewed and appraised by three reviewers. Methodological quality was quantified using the American Speech-Language-Hearing Association's levels of evidence. In total, 21 studies were included in the review. We argue that there is a need to develop a more thorough guide for AT professionals in the process of AT assessment for children with Autism Spectrum Disorder.

Keywords: *innovative technology, autism spectrum disorder, assistive technology, social skills, speech difficulties, motor skills*

Introduction

Autism Spectrum Disorder (ASD) is related to a range of significant impairments in speech disorders, social interaction, and poor motor skills (American Psychiatric Association, 2013). Individuals with autism are characterized by repetitive and ritualistic behavior and often have symptoms of attention deficit hyperactivity disorders (ADHD) while their cognitive development does not follow a homogeneous path (American Psychiatric Association, 2013). Furthermore, there has been a steady increase in diagnosis of the disorder (Tarbox, Dixon, Sturmey, Matson, & SpringerLink, 2014). However, it is still unknown if the disorder is due to an individual being born with the disorder or increased awareness and improved diagnosis (Tarbox, Dixon, Sturmey, Matson, & SpringerLink, 2014). Regardless of the cause, as the numbers of ASD continue to rise, the need for intervention is more demanding than ever. Children with autism need language, social and behavioral, and motor skills assistance in order to become independent and successful (Ennis-Cole & Smith, 2011). Additionally, the majority of them encounter difficulties to achieve their daily life goals and they rely on continuous support from parents and/or caretakers (Farley et al., 2009).

Assistive Technology
Assistive technology (AT) can play an important aspect of intervention for children with disabilities. Assistive technology has the potential to alter learning opportunities for individuals with ASD. The Individuals with Disabilities Education Act (IDEA, 1997), the Technology Related Assistance for Individuals Act (TRAIDA, 1988), the Americans with Disabilities Act (ADA, 1990), and the Rehabilitation Act (1973) define *AT* as "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Cardon, Wilcox, & Campbell, 2011, p. 169).

The majority of research available exploring AT and children with autism spectrum disorder (ASD) involves picture systems and their ability to increase children's receptive and expressive language skills. To support the receptive language development, AT often takes the form of picture schedules to assist children with a variety of daily routines and activities (Cardon, Wilcox, & Campbell, 2011). In addition to the low-tech picture systems, research also indicates that high-tech voice output devices have been used to help children with autism between the ages of three and five years request food, help, and gain access to preferred activities (Cardon, Wilcox, & Campbell, 2011). Assistive Technology (AT) can address the specific needs of a child with autism's speech difficulties, little social interaction, and poor motor skills. AT can enable them to experience more independent living. AT can be defined as specialized tools that allow those with a disability to independently and fully participate in schools (Ennis-Cole et al., 2011). Assistive Technology includes, but is not limited, to both non-technical auxiliary aids, mechanical and electrical devices, computer software, simulations, virtual reality, and augmentative and alternative communication devices. These technologies can help a child with a disorder, such as ASD; accomplish a task that is otherwise extremely difficult or impossible without these tools (Ennis-Cole et al., 2011).

Purpose
Identifying effective interventions and supportive strategies for people with ASD is a critical issue for researchers, educators, and practitioners (Stasolla, Damiani & Caffò, 2014). The purpose of this systematic review sets out to examine and evaluate the impact of assistive technologies such as iPad applications, social robots, and neurological exams on speech difficulties, social interaction and the poor motor skills of children in the autism spectrum disorder.

Method

Selection of Research Articles
Between January 2014 and April 2015, the following three electronic databases were searched: PubMed, CINAHL, and PsychINFO. To capture as many relevant citations as possible, a wide range of medical, health and educational databases were searched to identify primary studies of the effects assistive technology on children with autism. To reach this target, we limited the search to recent peer-reviewed articles, as they are more likely to be relevant and adhere to reporting standards. The search terms used were a combination of the following sets: set 1: *autism spectrum disorder* AND *assistive technology;* set 2: *assistive technology* AND *autism;* set 3: *autism* AND *assistive technology* AND *social skills; and* set 4: *innovative technology* AND *autism.*

Inclusion and Exclusion Criteria

Screening criteria were established to identify potentially relevant articles that met minimum methodological standards for acceptance. Inclusion criteria were: studies published between 2007 and 2015, cohort studies, case-control studies and randomized control trials that evaluated the use of assistive technology and focused on children with autism. Three reviewers screened the search results and all seemingly relevant publications. This was a process designed to eliminate only papers not meeting the criteria for inclusion.

Selection of Studies

The titles, keywords, and abstracts of the papers identified by the electronic databases were screened for potential relevance by three researchers. This effort resulted in 739 citations from which relevant studies were selected for the review. The full papers of the remaining 21 citations were assessed to select those primary studies pertaining to assistive technologies impacting speech, social interactions, and motor skills. Studies focusing on adults were excluded, as the main focus of the review is on children with ASD. After reading the full texts of the selected articles, the 21 most significant evidence-based articles were selected for further analysis in the review. See flow diagram in Figure 1.

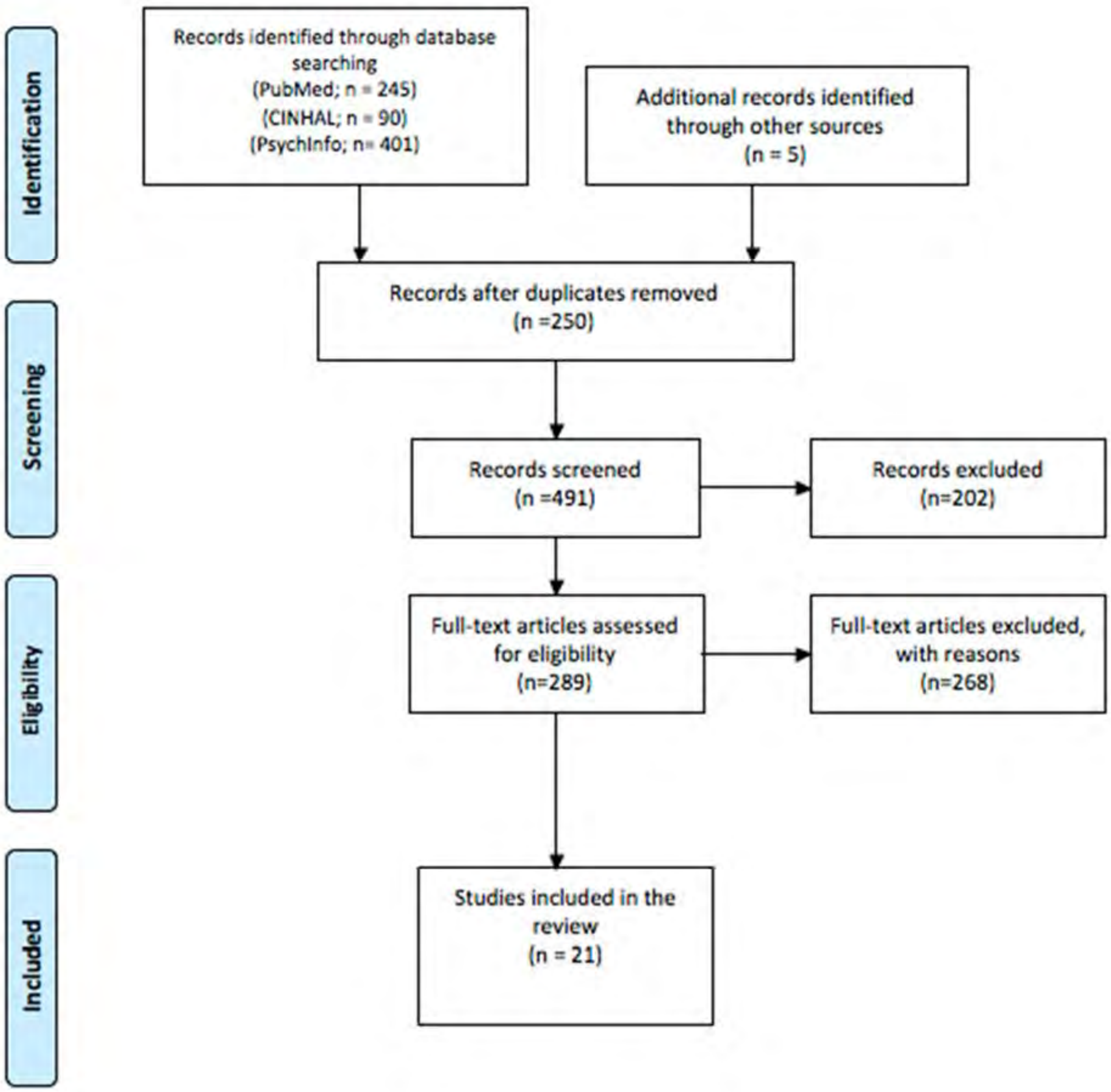

Figure 1. Study flow diagram for review of studies pertaining to assistive technology and ASD.

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

Results

Twenty-one studies were identified that met the inclusion criteria. The review used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and guidelines to ensure appropriate and transparent reporting of results (Moher, Liberati, Tetzlaff, & Altman, 2009). Results are summarized in terms of speech difficulties, social interaction and poor motor skills. The main findings are summarized in Table 1, Table 2 and Table 3.

Speech Difficulties

Ennis-Cole and Smith (2011) conducted a case-control study in which a large sample size of 85 participants was recruited between the ages of 10 to 17. The outcomes were positive across all studies as they successfully increased a variety of skills of communication, which also increased other skills such as joint attention, self-help, task completion, motivation, and appropriate behavior (Ennis-Cole & Smith, 2011).

Sampath, Agarwal, and Indurkhya (2013) conducted a case-control study using AutVisComm, an assistive communication system. This assistive communication system was developed in collaboration with teachers and parents of children with autism. The study included 24 children with autism all of which were eight years of age. The goal of the study set out to utilize AT, or application AutVisComm, as a means to assist a child in learning to request his or her desired object. Each child had two one-on-one sessions per week with a teacher, in which a food item was placed out of reach of the child and close to the teacher. To receive the food item, the child had to request the AutVisComm and press the appropriate picture on the screen. If they completed this on their own, it was considered to be an independent (IN) response. If the child needed a verbal prompt from the teacher, it was considered to be a verbal prompt (VP). Finally, if the child still did not respond after a VP the teacher would physically assist the child (Sampath et al., 2013). During the initial sessions most children needed to be physically assisted, but as time pressed on the need for this became less frequent and most children started responding to VP. An important finding in this study was that while concentrating on usability of AT for the children was important; the usability for caretakers also needs to be considered (Sampath et al., 2013).

Venkatesh, Greenhill, Phung, Adams, and Duong (2012) conducted a case-control study with 16 autistic children between the ages of two to seven. This group of scholars created an iPad-based application called Playpad that provides automated multimedia early intervention for children with autism. This application teaches basic skills designed by trained therapists, software for delivering therapy activities, and collecting progress results. Over a course of four weeks, therapy using the application was implemented and incorporated into the children's daily activities at home. The application specifically increased receptive and expressive language skills using partner activities in which the child and parent interact with the iPad and each other (Venkatesh et al., 2012). To increase expressive language, Playpad presents the image of an object and the child is required to verbally name it. Expressive language requires the child to use language as an expression, where the Playpad application says the name of an object and the child selects the image on Playpad (Venkatesh et al., 2012). To increase receptive language, Playpad presents pictures of objects from the categories and prompts the child to identify the correct object. Receptive language requires the child to use language receptively, where the Playpad application shows an object and the child names it (Venkatesh et al., 2012). This particular application was extremely successful because it not only incorporated a reinforcement system to motivate the child participating, but tracks and records each trial conducted. Over time, the children in this study decreased the number of errors created and the level of prompting needed, along with an increased number of correct responses (Venkatesh et al., 2012).

Ganz, Boles, Goodwyn, and Flores (2014) conducted a case-control study that included children with autism between the ages of 8 to 14. The study used computer-based visual scripts on vocabulary, and found that all the participants showed an increased use of verbs or nouns with the treatment materials. Also, all of the children required less prompts as the trials progressed over time.

Hill, Belcher, Brigman, Repper, and Stephens (2013) conducted a study with eight participants over the age of 18 with ASD in which the use of the iPad as an AT was tested. All participants at the beginning of the trial had difficulty in communicating and engaging socially while at the workplace, which resulted in a decrease of productivity (Hill et al., 2013). This study found that the use of the iPad's many features helped enhance interpersonal skills needed to communicate and contribute to a positive work experience. An important note in this study was that while the iPad does not replace the need for therapeutic engagement, this type of intervention does indeed improve daily communication for those with ASD (Hill et al., 2013). As described in Table 1, there were a wide variety of high technology AT tools tested and used included voice output communication aids, micro-switch communication systems, touch-sensitive screens, and computer-based language tools.

Kasari et al. (2014) conducted a randomized control study of 61 children with ASD. The study examined the effects of communication interventions which utilized an AT tool created to improve "spontaneous, communicative utterances in school-aged, minimally verbal children with autism" (Kasari et al., 2014, p. 635). The children were randomly assigned a condition of the "developmental/behavioral intervention with or without the augmentation of a speech-generating device (SGD) for 6 months with a 3-month follow-up" (Kasari et al., 2014, p. 2). SGD is a communication AT intervention that "displays symbols that produce voice output communication when selected" (Kasari et al., 2014, p. 3).

In a longitudinal study, the treatment was broken into two phases. In Phase one, all children received 21 one-hour sessions for three months with a clinician, utilizing an SGD. In Phase two, all children received 24 one-hour sessions, for three months with their parents present. It is noted that in phase two, parents received "systematic parent training consistent with the treatment variation to which the child was assigned" (Kasari et al., 2014, p. 5). This experiment, utilizing adaptive interventions, found that in a short amount of time all children improved significantly in spontaneous communication and utterances (Kasari et al., 2014).

Table 1
Results of Assistive Technology Impacting Speech Difficulties

Author	Sample Size	Type of Study	Age of Participants	Measures	Main Findings
Ennis-Cole & Smith (2011)	85	Case-Control	10-17 years	Variety of high-tech AT tools: PDAs, robots, vibrating pagers, switch training, voice output communication aids, microswitch communication systems, touch-sensitive screens, and computer-based language tools	Devices were successfully used to improve a wide variety of skills including communication, self-help, motivation, and appropriate behavior
Sampath et al., (2013)	24	Case-Control	7-8 years	AutVisComm	This application was used at a special school for autistic children in whom each child had two one-on-one sessions per week with a teacher. In order to receive a food item, the child had to use AutVisComm to choose the appropriate picture on the tablet. As sessions progressed, the need for PA and VP became less frequent and the children starting responding independently.
Venkatesh et al., (2012)	16	Case-Control	2-7 years	Playpad	One month of intervention improved receptive

					and expressive language through trails of matching tasks, verbal interaction, and reinforcement. Learning was apparent because of the decreasing number of errors and increasing proportion of correct responses and unprompted responses.
Ganz et al., (2014)	3	Case-Control	8-14 years	Tablet computer-based visual scripts on vocabulary	Results indicated that all the participants showed increase use of verbs or nouns with the treatment materials, all the participants required less invasive prompts as the project progressed.
Hill et al., 2013	8	Case-Control	18 years +	iPad	Support not only independence in daily living, but enhanced the interpersonal skills needed to communicate and contribute to a positive work experience and success.
Kasari, et al., 2014	61	Randomized-Control			

Social Interaction

Cramer, Hirano, Tentori, Yeganyan, and Hayes (2011) conducted a cohort study involving sixteen students between the ages of six and ten years old. The study focused on the interactive tool vSked used in a classroom based setting. Unlike some other studies in this systematic review, vSked focuses on the classroom as a unit rather than just the individual. The use of vSked encourages group practices within the classroom using visual schedules, choice boards, and a token-based reward system (Cramer et al., 2011). The study was conducted in two autistic classrooms over the course of a year. Focusing on a sense of classroom community, the screens in front of the classroom allowed students to see their progress throughout the day as well as seeing their classmate's progress. By awarding tokens as they complete specific tasks and displaying it in the front of the classroom, this encourages students to continue working diligently as well as encouraging their classmates. It is essential for children to feel important and have a sense of community, especially autistic children, and that is the main focus of vSked.

Escobedo, Nguyen, Boyd, Hirano, and Randgel (2012) observed a cohort of twelve children, three who were autistic and nine who were neurotypical (NT), between the ages of eight and eleven year olds in a public school located in Southern California. They studied the examined the effects of a mobile assistive technology named MOSOCO: A Mobile Assistive Tool to Support Children with Autism Practicing Social Skills in Real-Life Situations. MOSOCO is a social compass interactive tool that works on Android smartphones with features that encourage children to make good eye contact, have appropriate spatial boundaries, engage in conversation, identify appropriate communication partners and end an interaction in an appropriate way (Escobedo et al., 2012).

The three students with autism were paired up with NT students as their interaction partners. Video cameras were set up during social exchanges to observe non-verbal communication. Weekly interviews were then conducted to ask participants how the technology was working and how it is impacting their interactions (Escobedo et al., 2012). MOSOCO had a positive influence on the social aspect of children with autism spectrum disorder and changed the group dynamic of student groups. This study can be related back to vSked in that they both work on the individual social skills, but it also focuses on the group dynamic in a school based setting.

Cannella-Malone et al. (2016) conducted a study in which video prompting was utilized to teach new leisure skills. This study included nine students with severe disabilities, including autism spectrum disorder, aged 10 to 22 years (Cannella-Malone et al., 2016). Prior to the study, parents and teachers completed an interview with each student to rank and select specific leisure tasks they are interested in or have done in the past. All videos used in this intervention were created from the perspective of a spectator, and displayed on an iPhone 4. Each video began with a verbal prompt to begin the task, and consisted of a series of short clips for each step of the task. Video prompting was effective in teaching 14 new leisure skills to eight out of the nine students including origami, darts, Lite-Brite, dominos, and painting nails (Cannella-Malone, et al., 2016). This study suggests that the development of new leisure skills leads to an increase in many other skills such as social interactions, positive emotional effects, and increased activity level (Cannella-Malone et al., 2016).

Kim et al. (2013) conducted a randomized controlled experiment to study the effects of a social robot and its interactions of children with autism. Twenty-four children between the ages of four and twelve diagnosed with high-functioning autism spectrum disorder were observed. A social robot was programed with ten social interaction behaviors and three non-verbal movements designed to replicate a social interaction. An adult stimulus was present during all robot-simulated situations to control the movements of the robot. It was noted that most children did not interact with the adult while the robot was present, only one participant verbalized suspicion that the adult was controlling the robot (Kim et al., 2013). It was found that there was more verbalization while interacting with the robot. This study suggests that in comparison to real therapy support animals, robot animals can be used as a better interactive tool for autistic children. In that, they can be specially customized for each child, controlled by an adult more easily, and are much more affordable compared to training a service animal (Kim et al., 2013).

Lang et al. (2014) performed a cohort study using video self-modeling. Two students with autism spectrum disorder all who are between the ages of four and five years old were the participants. First, there was video footage of children with ASD interacting with other children. During this time, teachers would encourage students to interact more with their peers. After the footage was captured, the raw footage was edited to cut out the teachers interacting with the children as well as poor behavior or solitary play. The students then watched the footage for seventeen school days. Students were then brought out to play with fellow classmates and teachers were instructed not to interfere. The goal was to prompt participants to socially interact more with peers and increase the occurrence of this without the encouragement of teachers. The results indicated an increase in overall social interactions.

Ploog, Scharf, Nelson, and Brooks (2013) conducted a case-control study using computerized visual representations of emotional facial expressions to simulate real life situations. The use of a 3D avatar was used in three stages to study and improve emotion recognition in children with autism spectrum disorder. Stage one, participants were asked to interpret what emotion the avatar was feeling. Stage two participants were given different scenarios and were asked to guess what emotion the avatar was feeling based on that specific scenario. In stage three, the children were a certain emotion that the avatar was feeling and was asked what scenario or event they thought caused this emotion. This virtual environment indicated that children were able to communicate more effectively with other people and that 90% of the participants were able to interpret, recognize and predict emotions from the avatar (Ploog et al., 2013).

Wainer and Ingersoll (2011) conducted a randomized control study with ten participants' ages 16 to 40 using computer treatment. Participants were randomly assigned to a computer treatment group or a no-treatment control group. This computer treatment program was an interactive program that used photographs of faces and eyes. There was a significant increase in emotion identification of the pre-test to post-test. This study relates to the previous studies in that it worked to improve the social skills and emotion recognition in children with autism spectrum disorder.

Table 2
Results of Assistive Technology Impacting Little Social Interaction

Author	Sample Size	Type of Study	Age of Participants	Measures	Main Findings
Cramer et al., (2011)	16	Cohort	6-10 years	vSked	Promoted student independence and encouraged consistency and predictability as well as socialization within the classroom between students as well as staff.
Escobedo et al., (2012)	12	Cohort	8-11 years	MOSOCO	Students learned the basic proper steps to a social interaction including the DO's and DON'Ts and how to help others interact. Learning to apply these skills outside of the classroom was key.
Cannella-Malone et al. (2016)	9		10 to 22 years		
Kim et al., (2013)	24	Randomized Controlled	4-12 years	Social Robots	More verbalization during robot interactions. Found that robot animals serve as a better interactive tool for children rather than real live animals, due to the fact that robots can be customized, controlled and more affordable.
Lang et al., (2014)	2	Cohort	4-5 years	Video self-modeling	Students with ASD were able to learn how to visualize themselves being successful in social situations. Demonstrated an increase in social engagement that was maintained after the study concluded.

Ploog et al., (2013)	34	Case Control	N/A	CAT (3-D Avatar)	Was found that 90% of participants were able to interpret, recognize and predict emotions in the avatar. Which lead to children being able to communicate more effectively with other people in real life situations.
Wainer et al., (2011)	10	Randomized Controlled	16-40	Computer treatment	Participants in the computer treatment group made significant improvements in emotion identification compared to the control group.

Motor Skills
Ament et al. (2015) conducted a case-control study to find evidence for the specificity of motor impairments such as in catching objects and balance in children with autism. The study consisted of two hundred participants with an age range between eight to thirteen years old. All of the children participating needed to meet on the basis of a clinical judgment and if they were diagnosed. The participants for this study were pulled from local schools, pediatrician's offices, outpatient clinics, and the local Autism Society of America chapters. The results of the study indicated that two of the standard scores had main effect on the group [F (2, 197) = 62.04, p < 0.001]. Conferroni post hoc test was used during this study to show the differences in the MABC-2 score for the groups. "This test revealed there was a big difference in the total score of MAB-C2 between the TD group (M = 8.90, SD = 2.52), ADHD group (M = 6.38, SD = 2.67), and ASD groups (M = 4.14, SD = 2.19)" (Ament et al., 2015, p. 748).

Barbeau, Meilleur, Zeffiro, and Mottron (2015) conducted a case-control study, which included 39 people ranging from age 14 to 30 years old. The people used in this study were randomly found from database of the Specialized Autism Clinic at the Rivie re-des-Prairies Hospital located in Canada. The study was on comparing motor skills in autism spectrum individuals with and without speech delay. For this study the researchers excluded individuals with a visual impairment, used alcohol (more than two drinks a day) or drugs. The procedure for the study addressed the handedness assessment. This assessment includes ten items monitoring a subject's preferred hand during activities such as throwing a ball. A motor skill assessment was also was completed by subjects. Subjects were required to pay a game with a wooden board made of two parallel rows of ten holes each of them are eight inches apart. "A trial was considered valid when no pegs were dropped and no significant distraction interfered" (Barbeau et al., 2015, p. 685). Simple reaction time was a visual trigger that was used to obtain the approximant movement speed. The participant's task was to look at the computer screen and each time a black box would appear to the right of the screen they needed to press the button. Results of this study concluded that the use of three standard deviation (3 SD) instead of two standard deviation (2 SD) not affect the overall results. "Planned contrasts revealed that AS-SOD participants were 772, 876, and 913 milliseconds (ms) slower than typical individuals in the DH" (Barbeau et al., 2015, p. 686).

Behere, Shahani, Noggle, and Dean (2012) study was on the motor functioning in Autistic Spectrum Disorders. This is a case-control study; this study focuses on 26 individual's age ranging from six to twenty years old. These individuals were referred for a neuropsychological evaluation. Thirteen of the 39 original participants were excluded from the study because of missing data. This study was divided with the first group having sixteen patients diagnosed with autism with an age range of six to twenty-three, education ranging from first to twelfth grade and the second study consisting of 10 participants with Asperger's disorder age ranging from eleven to thirty-two years old with an education of first to twelfth grade. Participants were administered a DWSMB which is "standardized and norm-referenced measure of cortical and subcortical sensory/motor functioning" (Behere et al., 2012). The participants were then scored based on two different score values of 'W' (different sampling) and 'WD' (norming sample). The results of this study was found by using SPSS "No univariate or multivariate within-cell outliers, at [alpha]=0.001, were found. Assumptions of normality, linearity, homogeneity of variance/covariance matrices, and multicollinearity were met. Also, the covariate of age was found to be reliable for covariance analysis" (Behere et al., 2012, p. 90).

Lloyd, MacDonald, and Lord (2013) study was on Motor Skills of toddlers with Autism Spectrum Disorder. This is a cohort study; this study focuses on a hundred and sixty-two participants ranging from age twelve months to thirty-six months old. This study took place in three different areas including the North Carolina state-funded autism centers; the Chicago autism clinic associated with a private university, and an autism center in Michigan. The participants in this study are part of two investigations for toddlers at risk to become autistic. All of the participants took place in the MSEL testing intended for babies who are from birth to sixty-eight months old. "Scores on the MSEL are organized into five domains including, gross motor, fine motor, visual perception (nonverbal problem solving), receptive language, and expressive language" (Lloyd et al., 2013, p. 4). The calculations that were used during this study was the ratio verbal IQ. This was calculated by taking the mean age; divide by chronological and multiplied by 100. The ratio non-verbal IQ was found by using the age equivalents from fine motor and visual perception tests. The results of the first study revealed no differences in motor skills between the three sites. However, this study showed even though the children had cognitive delays the older children in the study had more delays than the younger children. The second study showed that the fifty-eight children that are autistic in this study showed a delay in gross and fine motor skills, this means the children had significantly fallen behind their chronological age (Lloyd et al., 2013).

MacDonald, Lord, and Ulrich (2013) study was on the relationship of motor skills and adaptive behavior skills in young children with autism spectrum disorders. This is a cohort study focusing on a hundred and fifty-nine participants aging from fourteen to forty-four months. The type of testing used for this study is GML testing; Almost all of the data collected for this study was in an autism clinic. This study focused on testing the relationship between fine and gross motor skills in autistic children. Both gross and fine motor skills were measured utilizing The Mullen Scales of Early Learning (MSEL) (MacDonald, Lord, & Ulrich, 2013). The results for the study were dependent variable on "fine motor skills, nonverbal problem solving, ethnicity and calibrated autism severity" (MacDonald, Lord, & Ulrich, 2013, p. 6). No interactions happened during these results and the fine motor skills were significant of adaptive behavior composite ($p < .001$), daily living skills ($p < .001$), adaptive social skills ($p < .05$) and adaptive communicative skills ($p < .001$).

LeBarton and Iverson (2013) conducted a cohort study on the fine motor skills that predict the expressive language in infant siblings of children with autism, also diagnosed with ASD. Based off of thirty-four participants age ranging from twelve to thirty-six months, a measure of fine motor skills were used to tap motor planning and fine motor control for the children ranging in age from 12-18 months they also used a measure of vocabulary for the children at 36 months. Along with using both of those during this study they used standardized observational measures of fine motor and language skills as a "complementary source of information" (LeBarton & Iverson, 2013). The results of this study showed that the "composite scores were significantly lower for the HR group ($M = 3.62$, $SD = 1.86$) than the LR group ($M = 5.20$, $SD = 1.41$) ($U = 215.0$, $p = .001$)" (LeBarton & Iverson, 2013, p. 6).

Mostofsky, Burgess, and Larson (2008) study examined increased motor cortex white matter volume as a predictor of motor impairment in children with autism. The case-control study included 56 participants ranging in age from eight to twelve years old. The type of testing used during this study is the Physical and Neurologic Examination of Subtle Signs (PANESS). The study's goal was to see if the white matter in the primary motor cortex of these children would predict or not predict impaired motor skills in children with Autism. The results for this study had concluded that the groups did not differ from the amount of age difference between each person in the study (Mostofsky et al., 2008).

Table 3
Results of Assistive Technology Impacting Poor Motor Skills

Author	Sample Size	Type of Study	Age of Participants	Measures
Ament et al., (2015)	200	Case-Control	8-13 Years	Clinical judgment, Autism Diagnostic Observation (module 3), stimulant medications, Performance-based assessment evaluating motor skill ability (MABC-2)
Barbeau et al., (2015)	39	Case-Control	14-30 Years	Handedness assessment, Motor Skill assessment, Clinical diagnosis
Behere et al., (2012)	26	Case-Control	6-20 Years	Neurological exams, DWSMB, MANOVA
Lloyd et al., (2013)	162	Cohort	12-36 Months	MSEL
Macdonald et al., (2013)	159	Cohort	14-44 Months	GLM testing,
LeBarton et al., (2013)	34	Cohort	12-36 Months	Non-parametric Mann-Whitney tests.
Mostofsky et al., (2008)	56	Case-Control	8-12 Years	Physical and Neurologic Examination of Subtle Signs (PANESS)

The three tables in this section discuss the main findings of research conducted on the impact of assistive technology on children in the autism spectrum disorder. Table 1 explains how the studies pertaining to how AT impacts speech and communication difficulties. Table 2 addresses the information found on how AT impacts social interaction, and Table 3 showcases the studies that found how AT impacts poor motor skills.

Discussion

The majority of the studies found during the search for language improvement and motor skills in autistic children included case-control studies. All of the studies range in age from the time of birth until the age of thirty years old. The average amount of participants in the studies was ninety-six people, ranging from twenty-six up to two hundred participants. The main similarity between the studies on motor skills in children with autism is that the participants were randomly selected and found in an Autism Society of America area. All of the studies found impacting speech in people with ASD were similar in that they either created an application for a tablet or used an iPad.

Studies that focus on the development of social skills in autistic children aim to improve social interactions as well as emotional recognition. The majority of the studies used computer based technology in a classroom setting with both the individual as well as the collective body. Video modeling was also found to be an important tool helping participants improve their emotion recognition as well as social skills. The main takeaway from these studies is that after repetition there was a positive improvement. A sense of success and independence is key for all children but especially for children with autism spectrum disorder.

Limitations and future research

The promising outcomes of this particular systematic review indicate that the use of assistive technology devices with autistic children is warranted, and that available evidence indicates that the devices are likely to promote more effect speech, greater social interaction, and better motor skills of children in the autism spectrum. The effectiveness of assistive technology devices is no guarantee that children with ASD will be routinely used. Additionally, findings showed that large numbers of investigators failed to use evidence-based training procedures. Thus, the basic questions that remain open is the importance of future research regarding the effective use of AT and various procedures applicable to individuals with autism and the training or education of professionals and parents.

Conclusion

This systematic review not only discussed the impacts of assistive technology on language, but on social interaction and motor skills. All of the studies selected showed a positive increase in all three objectives with the assistance of AT. This information is not only beneficial to children with ASD, but teachers and parents. Studies focused on the individual as well as students as a collective body. Studies also focused on the importance of an individual with autism to have a sense of independence and a sense of belonging in the community. With new technologies rising, we will be able to better support children with ASD in various aspects of their lives. In conclusion, we have learned that all of the studies we used show an increase in abilities of children with autism.

Autism is a growing occurrence in the world and it is best if people are well informed by researching how technology impacts speech, social interaction, and motor skills. Furthermore research and assessment is needed to measure the benefits of individualized assistive technology tools to aid with other complications associated with ASD. Additionally, future research regarding best practices in teaching approaches and accessibility to assistive technology to help individual ASD and their families should further be explored.

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