



Use of iPad and Mobile Devices in Children with Autism Spectrum Disorders: A Systematic Review

Anna Ebert and Sabiha Parveen*

Department of Communication Sciences and Disorders, Oklahoma State University, United States

***Corresponding author:** Sabiha Parveen, Assistant Professor, Department of Communication Sciences and Disorders, Oklahoma State University, 042 Murray Hall; Stillwater, OK 74078, United States, Tel.: 405-744-5116; Fax: 405-744-8070, E-mail: sabiha.parveen@okstate.edu

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ABSTRACT

Autism spectrum disorder (ASD) is a developmental disability often associated with challenges in behavior and communication. Approximately 1 in 42 children have ASD and its prevalence is expected to remain constant based on current trends. Children with ASD can have a range of communication skills including being completely non-verbal to having a large vocabulary and being able to converse about certain topics in rich detail. Children with ASD have been reported to learn more effectively from computerized assistance compared to traditional methods. With 95% of people in the United States owning some form of mobile device, this modality of intervention can be easily accessed by most individuals. Although prior researchers have examined the possible benefits of iPad-based intervention among individuals with ASD, the overall evidence for these types of intervention is currently lacking.

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The current study is therefore an attempt to determine the existing evidence for the use of iPad and mobile devices as the primary language intervention method for children with ASD. Language interventions could include receptive and expressive language based activities with focus on areas of pragmatics, semantics, and syntax. A thorough electronic search was conducted utilizing 14 databases followed by the screening of articles based on pre-determined inclusion and exclusion criteria. The results of this review suggest that iPads and mobile devices may be effective for language intervention among children with ASD. However, findings from the existing literature need to be interpreted with caution due to lack of high quality study designs, relatively small sample sizes, and limited generalizations of targeted intervention outcomes. Additional studies are warranted to further examine the full scope and benefits of iPad and mobile devices among children with ASD.

Key Words: iPads, Mobile devices, Review, Language intervention, Autism spectrum disorders

INTRODUCTION

Autism Spectrum Disorder

Autism spectrum disorder (ASD) is defined by the Centers for Disease Control and Prevention (CDC) as a developmental disability, which can result in serious challenges in behavior, communication, and socialization [1]. It is also noted by the CDC that individuals with ASD have methods of learning, focusing, and reacting that differ from most people. Approximately 1 in 42 children have ASD as estimated by recent reports [2], with boys being 4.5 times more likely to have the disorder than girls [3]. A great deal of variance in terms of communication abilities in children with ASD is reported by the National Institute of Deafness and Other Communication Disorders (NIDCD) [4]. This variance is made apparent as their communication skills can range anywhere from being completely nonverbal and without any significant communication skills to having a mastery of an extensive vocabulary and possessing the ability to converse about a number of topics in great detail [4].

Categories of Autism Spectrum Disorder

According to the criteria provided by NIDCD [4], the typical communication of children with ASD can be categorized into four major patterns. The first is “repetitive or rigid language”, which describes how many children with ASD produce utterances that in no way relates or has significance to the given conversation. This can include echolalia, in which the child will imitate a word, phrase, or sentence that they have heard. This pattern can also include the child making use of the same phrase every time they initiate a conversation, even if it is not always appropriate for the conversation or conversational partners. The second pattern identified by the NIDCD is “narrow interests and exceptional abilities”, which describes how certain children with ASD may have the ability to speak in detail about a subject that they find particularly interesting, although they may be unable to participate in a conversation with another individual. The third pattern is “uneven language development” which explains that although most children with ASD are able to develop some level of communication skills,

their communication skills typically do not reach a level that is considered normal, and their progression in speech and language development is typically inconsistent. They may acquire a speech or language skill rapidly in the language domain of semantics for example, but may be greatly lacking in others. The fourth pattern identified by the NIDCD is “poor nonverbal conversation skills”, which explains that many children with ASD have difficulty applying body language or gestures to language and understanding their meaning in others. They may also have difficulty initiating or maintaining eye contact.

According to the criteria developed by NIDCD, communication difficulties among individuals with ASD can culminate in behavioral problems, which stem from a need to express themselves when expressive language is not fully available to them. These behaviors can include inappropriate actions such as vocal outbursts, self-injurious behaviors, and aggressive behaviors [4]. Pragmatics can be defined as the aspect of language concerned with the purpose of communicating, communication frequency, topic maintenance, attending to topic changes, conversational turn-taking, and the ability to modify aspects of speech based on the specific listener or social situation [5]. According to Boonen et al. [6], children with ASD who have pragmatic deficits are more likely to display behavioral issues when compared to peers with ASD without pragmatic deficits. In addition to difficulties with pragmatics, Davis et al. [7] reported that children with ASD who have a decreased level of communication skills have an increased level of anxiety. It is important to note that diminished communication skills in children with ASD can have a serious and negative impact on their ability to function socially. For example, a child who is unable to express themselves may have difficulty finding an appropriate way to communicate their emotions to peers, causing them to struggle in forming social relationships.

Expressive/Receptive Language in Autism Spectrum Disorder

While difficulties with pragmatics is a well-known language deficit seen in individuals with ASD, deficits related to expressive and receptive language abilities are also common, although varied in intensity across the population [8]. According to Geurts and Embrechts [9], preschool-aged children with ASD have more difficulty with structural aspects of language when compared to pragmatics. However, school-aged children with ASD demonstrate more difficulty with the area of pragmatics as opposed to structural language [9]. Kwok et al. [8] performed a meta-analysis and found evidence that, contrary to common belief, children with ASD typically have a similar level of deficit for both their expressive and receptive language. It has often been reported through anecdotal evidence that children with ASD have higher abilities in their receptive language than their expressive language, but the meta-analysis yielded no evidence for this belief. This equivalency in receptive and expressive language skills suggests that children with ASD are often behind in their expressive and receptive language skills compared to age-matched peers. Thus, it is important that both receptive and expressive language are equally targeted among children with ASD [8]. Overall, numerous deficits in language skills for children with ASD often necessitate language intervention. A wide variety of language intervention types and modalities are currently available that can improve the language skills of children with ASD.

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Common Intervention Modalities

There are many language intervention modes that are appropriate for children with ASD as reported by the American Speech-Language-Hearing Association (ASHA) [10]. One modality of language intervention for children with ASD is utilizing visual supports or activity schedules. These can include photographs, objects, written words, or drawings, that serve as prompts for desired behaviors [10]. According to Olpakova [11], visual supports have been found to be extremely effective for increasing receptive language abilities as well as decreasing anxiety in children with ASD. Another modality described by ASHA is video-based instruction. Video-based instruction (sometimes referred to as video modeling) is a mode of intervention that utilizes video recordings of a model of a desired skill or behavior presented to an individual with ASD. These recordings are then imitated by the individual [10].

In addition to visual supports, augmentative and alternative communication (AAC) is a modality of language intervention for individuals with ASD, who are minimally verbal or nonverbal, that has been examined by several researchers. It can be described as a physical aid, which can include anything from a deck of picture cards to an application on an electronic device with an expansive vocabulary that serves as a possible replacement for verbal or written language [10]. A study conducted by Lal [12] found that children with ASD who used AAC intervention displayed improved expressive and receptive language as well as improved behavior and social skills. The last modality of language intervention described by ASHA for children with ASD is computer-based instruction, which can include any device that uses computer technology [10]. Some examples of this include applications on iPads, tablets, or phones or software designed for laptop and other traditional computers. Computer-based language interventions were found to be effective for children with ASD by several studies [13-15].

iPad/ Mobile Device Interventions

Because of continuing advances in technology, iPad and mobile device based interventions have become more commonly used means to increase language skills in children with ASD [16]. According to Williams et al. [15], children with ASD learn more effectively and are less resistant to learning from computerized assistance compared to traditional methods of learning to read. More recently, Alzrayer et al. [17] found that the use of iOS devices, such as the iPad, leads to an improvement in children with ASD's ability to communicate when used as a speech generating device. This suggests that iOS devices could be a promising modality for language intervention in children with ASD.

Based on the increasing interest in technology-based intervention methods for individuals with ASD, a systematic review of the use of iPad and mobile device based interventions for language in children with autism is necessary. As new technology continues to become available, it is important that a current review of this area is conducted to gather evidence-based practice on the use of iPads and mobile devices for intervention in communication skills for individuals with ASD. To the best of our knowledge, there is no systematic review currently existing that focuses on use of iPad and mobile devices for language-based intervention among children with ASD.

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One systematic review by Omar and Bidin [18] did look into the use of multimedia and reading interventions for children with ASD. However, this study did not focus on mobile devices and did not provide a broad look at language interventions. This study therefore aims to provide a review of existing studies related to iPad and mobile device interventions among children with ASD. Findings from the study will help in understanding the current trends and evidence regarding iPad and mobile device intervention for ASD related deficits. Thus, the specific research question is as follows: "Are iPad and mobile device language intervention methods effective for children with ASD?"

METHODS

Data Collection Measures

A thorough electronic search of the available literature using the databases Academic Search Premier, Global Health, Health.gov, Journal Storage (JSTOR), Linguistics and Language Behavior Abstracts, MEDLINE, National Center for Health Statistics, Open Access Journals, ProQuest, PsycARTICLES, PsycINFO, PubMed, Web of Science, and ERIC was conducted. These resources were selected to ensure that all relevant materials could be identified. During the electronic portion of the search, the "year" filter was set to 1995 to March 2018. The specific timeline was chosen due to changes in diagnostic criteria of ASD in DSM-IV in 1995 and more recent changes in DSM-V in 2013.

The terms used for the electronic portion of the search included: autism + iPad + intervention, autism + iOS + intervention, autism + tablet + intervention, autism + mobile + intervention, autism + iPod + intervention, autism + electronic + intervention, autism + technology + intervention. The rationale behind including the term "intervention" with all of the search terms is to minimize the number of results pertaining to screening or diagnostics. The term "language" was not included so behavioral interventions that could be considered as pragmatic in nature were not excluded and to prevent further limitations of search results.

The following criteria were utilized for inclusion in the study: (a) participants with a confirmed diagnosis of ASD (b) participants ranging in age from birth to 18 years, (c) articles that have been published in English, (d) articles that include one or more participants with a diagnosis of ASD regardless of diagnosis of other participants, (e) articles that at least include one or more iPad or mobile device based interventions focusing on one or more language skill, (f) articles that have been published between 1995 and present, and (g) at least one of the language areas (semantics, syntax, morphology, phonology, pragmatics, receptive language, expressive language) must be the primary area of intervention investigated by the article. In addition, the following exclusion criteria were considered during the article search process: (a) materials such as opinion papers, letters to the editor, pamphlets, or other sources that are not published in peer reviewed journals or prepared to be published in peer reviewed journals, (b) articles that include interventions other than those that are mobile device or iPad-based, (c) articles that include any form of AAC intervention, (d) articles that include assessment, diagnosis, or screening for language skills in children with autism, (e) interventions using technologies that are not iPad, tablet, smart phone, or other compact smart technology, and

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(f) interventions where the assistive technology is unspecified. For the purposes of this study, a mobile device was defined as a handheld computer tablet or any other device that is as compact or more compact than a tablet and includes computer technology [19].

All studies were selected based on two degrees of screening. The first author screened the titles and abstracts of the articles identified in the electronic and manual search. In addition, the first author also screened the list of references from the identified articles to determine any other relevant materials. The first author then read the selected articles in their entirety, while applying the inclusion and exclusion criteria. Appendices A and B include listing of inclusion or exclusion of articles based on PRISMA standards [20] as well as the screening process for the current review. Both the first and second authors then used the Critical Appraisal of Treatment Evidence (CATE) to synthesize information from the selected articles and assessed the quality of these studies independent of each other (Appendix C) [21]. **Table 1** includes a summary of all 28 studies that were selected for detailed review based on the screening criteria.

RESULTS

Participants' Ages and Diagnoses

Of the 28 studies selected for the current review, 25 studies included participants with ASD. Of the three that did not utilize participants, one was a systematic review [18], one was a report on previous work related to the Reggio Emilia-inspired programs [22], and one was an overview of an application for teaching children with ASD to understand facial expressions [27]. For the remaining 25 articles related to the use of iPad and mobile devices, a total of 293 participants were reported. The ages of the participants ranged from approximately 3 years to 17 years. Autism spectrum disorder made up the majority of diagnoses seen in these 25 articles, with 279 (98.9%) of the participants having some form of an ASD related diagnosis. Of the total 279 children with ASD, nine (3.2% of participants with ASD) were reported as having a comorbid condition including attention-deficit/hyperactivity disorder (ADHD), speech impairment, and Down syndrome. In addition to a diagnosis of ASD, four participants had a comorbid diagnosis of ADHD, three had a comorbid diagnosis of speech impairment, and two participants had a comorbid diagnosis of Down syndrome. The three participants who had no ASD related diagnosis were from the same study [34] with one child being diagnosed with Down syndrome and two being diagnosed with an intellectual disability.

Settings

Twenty-two of the selected studies reported on a setting for the study. Thirteen (i.e. 59%) of the studies occurred in a school setting. Three (i.e. 13.5%) of the studies occurred exclusively in the participants' homes. Among the remaining studies, two (i.e. 9%) occurred in a clinical setting, two in multiple settings (treatment rooms, play rooms, public places, and participants homes), and one (i.e. 4.5%) in an exclusively outdoor setting (Table 1).

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Authors	Design	Participants	AO	IA	PI	SV	M a i n t e - n a n c e	Generalization
Mitchell [22]	Review	n/a	Learning and development	n/a	n/a	N	N	N
Lindsey-Glenn et al. [23]	Case study	11-year-old male with ASD	Improved vocabulary	N	Y	N	N	N
Hourcade et al. [24]	Multiple case-study; quasi-experimental	26 children with ASD (elementary and middle school)	Improved social skills	N	Y	N	N	N
Kagohara et al. [25]	Delayed multiple-baseline across participants, intervention, follow-up	2 children with ASD (10 and 12 years)	Improved spelling	Y	Y	N	Y	N
Murdock et al. [26]	Multiple baseline across participants single-case design	4 children with ASD (49-58 months)	Increased play dialogue	N	Y	Y	Y	Y
Gay et al. [27]	n/a	n/a	Identification of facial expressions	n/a	n/a	n/a	n/a	n/a
Brown et al. [28]	Nonconcurrent multiple probe design across participants	3 children with ASD (4-7 years)	Production of untaught intraverbal responses	Y	Y	N	Y	Y
Ganz et al. [29]	Alternating-treatment design	3 children with ASD (8-14 years)	Vocabulary use	Y	Y	N	N	Y
Grosberg et al. [30]	Quasi-experimental	4 children with ASD (7-9 years)	Persistence in social initiation bids	Y	Y	Y	Y	Y
MacPherson et al. [31]	Multiple baseline design across participants	5 children with ASD (9-11 years)	Increasing complement behaviors	Y	Y	Y	N	Y
Irwin et al. [32]	Preliminary study	4 children with ASD (8-10 years)	Improvement of perceptual sensitivity to speech	N	Y	N	N	N
Boyd et al. [33]	ABAB design	8 children with ASD (8-11 years)	Improvement in social skills/relationships	N	Y	N	N	N
Lorah et al. [34]	Multiple baseline	2 children with ASD (3 and 4 years)	Listener responding skills	Y	Y	N	Y	Y
Spooner et al. [35]	Multiple probe across participants	5 children total with an IQ below 55, 2 with ASD (7 and 8 years)	Improved literacy skills	Y	Y	Y	Y	Y
Miltenberger et al. [36]	Multiple baseline	5 children with ASD (5-12 years)	Improvement of various behaviors	Y	Y	Y	Y	Y
Omar et al. [18]	Systematic review	Children with ASD	Improved reading skills	n/a	Y	N	N	N
Crutchfield et al. [36]	ABAB reversal design with an embedded multiple baseline across both participants	2 children with ASD (14 years)	Reducing stereotypic behaviors	Y	Y	Y	Y	N

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Authors	Design	Participants	AO	IA	PI	SV	Maintenance	Generalization
Zein et al. [37]	Alternating treatments design	3 children with ASD (9-10 years)	Reading skills	Y	Y	N	N	N
Fletcher-Watson et al. [38]	Randomized controlled trial	54 children with ASD (less than 6 years)	Social communication skills	N	Y	Y	N	N
Lorah et al. [39]	Multiple baseline	2 children with ASD (3 and 4 years)	Listener responding skills	Y	Y	N	Y	Y
Bono et al. [40]	Multiple baseline across single case study design	10 children with ASD (5-9 years)	Improve imitation and joint attention	N	N	N	N	N
Whitehouse et al. [42]	Multicenter, stratified, parallel-group randomized control trial	80 children with ASD (median age of 3.38 years)	Improved developmental/behavioral skills related to ASD	N	Y	N	Y	N
Browder et al. [43]	Single case, multiple probe across participants	3 children with ASD (8-10 years)	Literacy, reading, and comprehension skills	Y	Y	N	Y	N
Kinsella et al. [44]	Quasi-experimental	15 children with ASD (8 to 16 years)	Improved conversational and social skills	N	Y	N	N	N
Liu et al. [45]	Pilot case study	2 children with ASD (8 and 9 years)	Improved social communication and behavioral skills	N	Y	N	N	N
Jouen et al. [46]	Single blind exploratory study with two observation points	14 children with ASD (5-8 years)	Improved imitation and joint attention	N	Y	N	N	N
Sng et al. [47]	Multiple baseline design with probes across conversation scripts, single case study	1 child with ASD (7 years)	Improved on-topic conversational responses	N	Y	N	Y	N
Grosberg et al. [48]	Multiple baseline design	6 children with ASD (6-10 years)	Improved conversational speech	Y	Y	Y	Y	Y

Table 1: Summary of all 28 studies that were selected for detailed review

Intervention

Associated Outcomes

All 28 studies targeted at least one of the domains of language including phonology, morphology, syntax, semantics, and pragmatics. Among these, 23 of the studies targeted pragmatics, more specifically, skills such as reading

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comprehension, conversational skills, and nonverbal social behaviors. Three of the studies targeted semantics including receptive vocabulary, expressive vocabulary, and vocabulary related to literature. Two studies targeted phonology, which included improving correct spelling by encouraging spell checking and improving the sensitivity of perception to speech. In addition, one study targeted literacy skills. Finally, one study was nonspecific on the targeted language domain in relation to participants with autism.

Mobile Devices

All of the selected studies utilized an iPad or a mobile device (as defined previously) as a primary component of the intervention method. The vast majority of the studies (17) used an Apple iPad. **Table 2** includes details of all iPad and mobile devices and the applications used in the selected studies for the current review.

Authors	Mobile Device	Application/Software
Mitchell [22]	Unspecified tablet	Reggio Emilia inspired program
Lindsey-Glenn et al. [23]	Franklin Language Master 6000b (FLM-6000b)	n/a
Hourcade et al. [24]	Dell XT2 multitouch tablet	Unnamed applications
Kagohara et al. [25]	iPad	Video modeling
Murdock et al. [26]	iPad	Keynote
Gay et al. [27]	iPhone/iPad	Capture My Emotion
Brown et al. [28]	iPad	Microsoft Powerpoint
Ganz et al. [29]	iPad	iCommunicate app
Grosberg et al. [30]	Apple iTouch	Video modeling
MacPherson et al. [31]	iPad 2	Video modeling
Irwin et al. [32]	iPad	Listening to Faces
Boyd et al. [33]	iPad	Zody
Spooner et al. [35]	iPad	Go Talk Now
Miltenberger et al. [36]	iPad	Video modeling
Omar et al. [18]	iPad and Android devices	Variety of applications
Crutchfield et al. [36]	Samsung Galaxy 5.0 smartphone	I-Connect
Zein et al. [37]	iPad	Space Voyage

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Authors	Mobile Device	Application/Software
Fletcher-Watson et al. [38]	iPad	FindMe
Lorah et al. [39]	iPad	Language Builder
Bono et al. [40]	Unspecified tablet	GOLIAH
Cardenas et al. [41]	Unspecified tablets and smart phones	Pictoaprende
Whitehouse et al. [42]	iPad	TOBY
Browder et al. [43]	iPad	Story map app, SMART notebook
Kinsella et al. [44]	Google Glass	Holli
Liu et al. [45]	Brain Power System (smart glasses)	n/a
Hourcade et al. [24]	Dell XT2 multitouch tablet	Unnamed applications
Jouen et al. [46]	Unspecified tablet	GOLIAH
Sng et al. [47]	iPad	Keynote
Gay et al. [27]	iPhone/iPad	The Conversational Coach
Grosberg et al. [48]	Unspecified cell phones	Text messages

Table 2: Mobile Devices and Applications/Software Used in Selected Studies

Experimental Designs

A variety of research designs were used by the 28 studies selected for this review. Specific information on the research design utilized by each study can be found in Table 1.

Systematic review

Out of the 28 selected studies, only one utilized a systematic review designed to assess the use of iPads and mobile devices as the means for various language interventions among children with ASD [18]. This systematic review found mobile devices such as iOS and android devices to be useful in targeting language skills. However this review was published approximately three years ago and included studies utilizing both traditional desktop computers as well as hand held smaller mobile devices.

Randomized Control Trials

Out of the 28 selected studies, only two utilized a randomized control study design. One used a design with only partial blinding of the participants [38]. In this study, the participants were only blind to what language skill was being targeted, which was pragmatics, but were not blinded to whether or not they were receiving the experimental treatment.

The study concluded iPads to be as effective as traditional therapy for children with ASD with no one mode indicating superior effects. The other randomized control trial utilized a double-blind design [42]. This study found that the TOBY app, which was delivered via an iPad, was useful in targeting language skills, specifically pragmatics, in children with ASD when compared to control group receiving traditional therapy only.

Quasi-experimental studies

A majority of the studies (i.e. 23 studies) used a quasi-experimental design and convenience sampling of participants. Of the studies utilizing a quasi-experimental design, 18 utilized a more complicated methodology such as an ABAB, multiple baseline, or multiple probe design. Five studies utilized more basic quasi-experimental designs, including single case studies or a series of case studies.

Nonexperimental design

Two studies in the current review were nonexperimental in nature. One was a nonexperimental review discussing some prior research related to a specific learning program inspired by Reggio-Emilia [22]. The other study was simply an overview of an app designed for facial expression recognition [27].

Overall levels of evidence

There are only three articles that are of a high research quality, which include one systematic review and two randomized control trials. The rest of the selected articles utilized a quasi-experimental or nonexperimental design. Moreover, a vast majority of the studies utilized a convenience sampling of fewer than ten participants with ASD.

Maintenance and Generalization

Maintenance and generalization are two key factors that provide a study's results with greater validity. Foxx and Mulick [50] state that maintenance could be considered as one of the most important factors following behavior modification when assessing an intervention for children with ASD. The ability of an intervention to elicit a change in behavior that remains over time is important as long-term maintenance is a primary goal of therapy. The ability to generalize a targeted behavior is considered to be a critical factor in assessing the usefulness of an intervention. In addition, it is also noted as a critical factor in assessing the validity of an intervention. Among the 28 selected articles, 13 studies (i.e. 46%) reported on maintenance of the skill in participants with ASD when targeted by the intervention procedures. In addition, 13 studies (i.e. 46%) reported on generalization of the skill targeted by the intervention procedures. In terms of the associated outcomes, pragmatic related interventions were the most prevalent and appeared to be generally successful. Other interventions, such as those focused on semantics and syntax were also successful.

Social Validity

Eight of the 28 selected studies (i.e. 28.5%) reported on the social validity of the intervention. Specifically, three utilized a parent questionnaire, two utilized teacher questionnaires, and two utilized responses from therapists working with study participants with ASD. Lastly, one study reported on social validity by using a variety of populations to assess the social validity of the intervention. This was the study by Spooner et al. [35] where the authors used a combination of different respondents including participants with ASD, teachers, para-professionals, and parents to determine the social validity of the intervention procedure.

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DISCUSSION

The purpose of this systematic review was to assess the effectiveness of iPads and mobile devices as a means of language intervention in children with ASD. A number of important findings and limitations were found which have been discussed in following sections have been found through this study. All of the studies utilizing an experimental design reported that the mobile devices (including iPads, tablets, phones, etc.) being used for the study were effective for targeting language skills among children with ASD. This suggests that iPads and mobile devices are useful tools for language intervention secondary to ASD. The available literature provided a wide range of participant ages and intervention settings, suggesting that the findings could be generalized to a variety of situations. In terms of social validity, among the eight articles that measured social validity, all reported effectiveness of the particular intervention. In terms of generalization and maintenance, a majority of the studies which reported on these areas found that generalization and/or maintenance of targeted skills in children with ASD were evident. Maintenance was assessed on an average between one and three months post treatment by the majority of the selected studies, although not all provided specific information on the timeline of their follow-up procedures. Lastly, of the articles that discussed the cost-benefit of the intervention method, all of them (i.e. 11 studies) stated that iPads, tablets, and other similar devices were cost friendly as compared to some other traditional therapy materials.

Specifically, some of the researchers discussed the long-term costs of traditional therapy, and found that the mobile device based intervention was less expensive.

Implications for Practitioners

One of the factors that brings interest to the use of iPads and mobile devices for language intervention is their cost effectiveness. It is important to note that the mobile devices for language intervention are often less expensive than traditional treatment tools, thus making it a more accessible means of treatment. The relatively cheap cost of these interventions will be important for practitioners to keep in mind when recommending an appropriate treatment for their clients. In addition, the relatively low cost of mobile devices allows for them to be used to augment traditional therapy. Another important benefit of using iPads and other similar mobile devices for language intervention includes the ease of use. As iPads and mobile devices are used by a large portion of the population, it is likely that children with ASD may have some familiarity with the general functioning and layout of the device. Further, iPads and mobile devices provide portability due to their small size and light weight. For practitioners, this would make them easy to use with clients who may be in a variety of locations or with children who like to move around. Finally, for parents, use of iPads and mobile devices as therapy tools would allow for their child to practice language skills anytime, such as during travel.

A number of the selected studies chose the participants' homes as the intervention setting, suggesting that the use of mobile devices in the home setting is a good method of targeting language deficits in children with ASD.

Therefore, the child could be using the iPad or mobile device to potentially augment their therapy experience while at home, in addition to the possibility of utilizing the device during a traditional therapy session.

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Limitations

While the results of this study indicate that the use of iPads and mobile devices are a positive means for targeting language in children with ASD, there are a number of limitations to be considered within the available literature. First, the lack of randomized and other high quality evidence studies with a large number of participants is a critical limitation in the existing literature. Second, it is difficult to conclude if these iPad and mobile device based interventions are useful for the ASD population as a whole or specific to certain sub-categories of ASD, such as those that are high functioning, have low cognitive skills, or have comorbid conditions. Third, at least three of the existing studies included participants with challenging behaviors which may have directly or indirectly impacted the intervention outcomes. For example, Murdock, Ganz, and Crittendon [26] reported that their 54-month-old participant displayed a disinterest in the activities of the study and would choose to wait until the allotted time for intervention was up instead of participating. This study initially only had three participants, but a fourth participant was introduced to address the effects the uncooperative participant might have had on the study.

In a different study, one of the 8-year-old children displayed behavioral issues including tantrums, uncooperativeness, and a lack of attention [30]. However, the researchers were eventually able to teach him the desired behavior. More recently, Browder, Root, Wood, and Allison [43] reported that two of their participants presented challenging behaviors during intervention.

The 9 and 10-year-old participants both had difficulty attending to a given task. To resolve this issue, the researchers gave these participants additional opportunities to learn the story elements for intervention than the third participant received. This aided in making up for the negative impact the behavioral issues would have had on the results of the study.

Future Considerations

Based on the current evidence, additional studies are warranted to further clearly examine the impact of iPads and mobile devices in language intervention for children with ASD. Future studies should look into factors that can make an application successful in targeting language in children with ASD.

Narrowing down these factors would provide important information for creating new applications in the future that will be more likely to be successful in targeting language. A detailed comparison of the available applications would also be useful. Perhaps most importantly, a greater number of randomized control trials with double-blinding can be useful to provide more evidence to the existing findings that so far suggest that iPads and mobile devices are beneficial for language intervention in children with ASD. Finally, the effect of experiencing an increase in screen-time by children with ASD using iPads or mobile devices as a language intervention needs to be researched in more detail. While these devices may be helpful in targeting language, it is important to ensure that use of iPads and mobile devices do not create a negative impact on another aspect of the child's behavior.

CONCLUSION

In conclusion, iPads and mobile devices may be effective for language intervention in children with ASD. However, the current findings should be interpreted with caution due to limitations seen in the existing literature. Future research should utilize high quality research designs including randomized control trial designs to provide greater generalization of the findings than is currently seen in the existing literature.

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Appendix A

TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I ²) for each meta-analysis.	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

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