J Autism Dev Disord (2015) 45:3792–3804
DOI 10.1007/s10803-014-2314-4

ORIGINAL PAPER

A Systematic Review of Tablet Computers and Portable Media Players as Speech Generating Devices for Individuals with Autism Spectrum Disorder

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Published online: 21 November 2014

Abstract Powerful, portable, off-the-shelf handheld devices, such as tablet based computers (i.e., iPad®; Galaxy®) or portable multimedia players (i.e., iPod®), can be adapted to function as speech generating devices for individuals with autism spectrum disorders or related developmental disabilities. This paper reviews the research in this new and rapidly growing area and delineates an agenda for future investigations. In general, participants using these devices acquired verbal repertoires quickly. Studies comparing these devices to picture exchange or manual sign language found that acquisition was often quicker when using a tablet computer and that the vast majority of participants preferred using the device to picture exchange or manual sign language. Future research in interface design, user experience, and extended verbal repertoires is recommended.

Keywords Autism spectrum disorder · Verbal behavior · Speech generating device · iPad · iPod

Introduction

Skinner (1957) defined verbal behavior as behavior that is emitted by a speaker and mediated by a listener. According to this definition, verbal behavior is intrinsically social behavior. Within the context of verbal behavior, multiple topographies of responding are acknowledged including, but not limited to, vocal speech, gestures such as pointing and manual sign language, and writing. Skinner (1957) asserted that within the context of verbal behavior, it is not the topography of the behavior, but rather the function of the behavior that is of interest. For example, a child saying, "Give me the red ball" and pointing at the red ball are equivalent if each results in another person delivering the red ball to the child. Skinner described five elementary verbal operants, which are functionally defined: mands, tacts, intraverbals, echoics, and autoclitics.

It is estimated that 30 % of individuals diagnosed with autism spectrum disorder (ASD) fail to develop vocal output capabilities (Wodka et al. 2013). For those individuals, it is often necessary to incorporate an augmentative and alternative communication (AAC) system when establishing a communication repertoire, or verbal behavior (Millar et al. 2006; Mirenda 2001, 2003; Ogletree and Harn 2001). The benefits of AAC to enhance verbal behavior (e.g., manding or requesting) are well recognized and can be used to either supplement (i.e., augment) limited speech or act as the primary (i.e., alternative) method of communication. The overarching goal of AAC is the development of generalized functional communication or verbal behavior within the natural environment throughout the individual's lifetime (Mirenda 2003). AAC systems are generally classified into two categories: unaided systems, such as manual sign language (MS) that do not require any equipment; and aided, which require the use of a device.

Unaided AAC, such as MS can be used to establish a communication repertoire; however it has several limitations when compared to aided AAC. One limitation is a reliance on the listener's knowledge of the communication system in the natural environment. For example, a clerk at a store and a server at a restaurant may not know sign language (Bondy and Frost 1994; Mirenda 2003), so in this

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case sign language would not be functional for the speaker. An additional limitation of the use of unaided AAC, such as MS, is that individuals with ASD and related developmental disabilities (i.e., Intellectual Disability; ID, Developmental Disability; DD) may demonstrate motor impairments and difficulty with imitative skills, which can limit the ability to acquire unaided AAC (Bondy and Frost 1994; Mirenda 2003). Finally, unaided AAC requires that the learner acquire many responses that are topographically dissimilar, whereas aided AAC require that the learner only acquire one response topography, such as pointing or exchanging a picture symbol (Bondy et al. 2004).

There are many aided systems of AAC, including picture exchange (PE) the picture exchange communication system (PECS), and, speech generating devices (SGD) or voice output communication aids (VOCA). In both PECS and PE, a speaker communicates with a listener through the exchange of a picture or word card that symbolizes a tangible item (e.g., cookie), activity (e.g., baseball), a response (e.g., yes), or a statement (e.g., "My name is…"). The PECS system was developed by Bondy and Frost (1994) and entails a six-phase training sequence; as such, if the training protocol does not follow their outlined six-phase sequence, the communication strategy should be classified as PE (Lancioni et al. 2007). Picture exchange (PE) is a system of picture-based communication that entails a training protocol that varies from those training procedures outline by Bondy and Frost (1994). SGD or VOCA are electronic devices that rely on the speaker's pressing of a picture, word, or other symbol depicting an item, activity, response, or statement on an electronic screen with enough force to evoke a synthetic speech output. Dozens of SGD devices exist and range greatly in cost and technological capabilities (Lancioni et al. 2007). For example, the GoTalk Express 32 is a SGD that contains 32 pre-programmed digitized outputs. The GoTalk Express 32 produced by Mayer-Johnson costs 241.95 US dollars according to its producers (http://www.mayer-johnson.com/gotalk-express-32/). The DynaVox Maestro has Wi-Fi capabilities allowing the individual to reprogram the device at any time; to include new items provided the device is in an area with wireless internet access. The DynaVox Maestro costs roughly 8,000 US dollars (http://www.dynavoxtech.com/products/maestro/interaact/).

Because SGD generate an intelligible audio output, SGD differ in an important way from PECS or PE in that the speaker is not required to first gain the visual attention of the listener prior to communicating and therefore, the listener can interpret the request even if he or she is not looking at the speaker (Lancioni et al. 2007). SGD also differ from the use of MS in that the speaker is not required to demonstrate topographically dissimilar fine motor movements for acquisition purposes. Additionally, SGD transmit digitized output that is synonymous to vocal output and thus can be easily interpreted by a listener. Finally, as the speaker acquires a larger verbal repertoire, storing, carrying and deploying PE picture symbols or PECS cards can become heavy and unwieldy. As an electronic apparatus, a SGD may potentially be able to store thousands of icons or "picture cards" in a much more compact and efficient manner.

The use of SGD as a method of AAC has been investigated in terms of communication acquisition, teaching strategies and comparisons to other methods of AAC, and to a lesser degree, participant device preference (e.g., Dicarlo and Banajee 2000; Thunberg et al. 2007; Sigafoos et al. 2003, 2009; Schepis et al. 1998; Beck et al. 2008a, b). Comparisons of SGD and PECS and/or PE in terms of the acquisition of a mand (requesting) repertoire have yielded mixed and/or inconclusive results. Bock et al. (2005) and Sigafoos et al. (2009) examined the acquisition rates of SGD and PE training and found comparable acquisition rates. Son et al. (2006) found that SGD training required fewer trials to criterion than PE training; however, Beck et al. (2008a, b) found that PECS training progressed faster than SGD when the PECS protocol outlined by Bondy and Frost (1994) was followed.

In summary, research shows that either SGD or PECS/PE is a viable option for mand (requesting or functional communication) training. However, practitioners must often choose between AAC systems and given the exorbitant costs associated with SGD that have substantial technological capabilities and the requirement of skilled technicians to repair devices after breakdowns (Shepherd et al. 2009) such devices may leave stakeholders (i.e., clinicians, teachers, parents) without alternatives to low or no technology AAC such as PECS, PE, and MS. However, given recent technological advances in the development of powerful, portable, and readily available, off-the-shelf handheld devices, such as tablet computers (i.e., the iPad®; Galaxy®) or portable media players (i.e., the iPod®), which can be adapted to function as a SGD, stakeholders are offered more affordable alternatives (for example, as of this writing an iPad® or Galaxy® tablet cost 150–400 US dollars.).

These consumer products can be employed as a less expensive SGD and thus more easily available to individuals diagnosed with ASD. These devices are also more readily available to parents and educators. Furthermore, the use of tablet computers or portable multimedia devices as a SGD may be more socially acceptable and less stigmatizing for these individuals. Moreover, the customization options of a tablet computer or portable multimedia device as a SGD are comparable to, and perhaps greater than, those SGD that posses substantial technological capabilities, but at a fraction of the price. Finally, and perhaps most

importantly, the use of a tablet or multimedia player allows the user greater flexibility and options in terms of the function of the device. That is, although the primary purpose of such a device may be to function as a SGD, the device can be used for secondary purposes including academic and leisure applications (i.e., Kagohara et al. 2013; Lorah and Parnell 2014).

The iPod touch was first released in 2007, the Apple iPad® and Samsung Galaxy® were first released in 2010.[1] Recent technology advancements in tablet based computing have made SGD more socially acceptable, affordable, and available thus necessitating the need for an evidence base for the use of such devices as a SGD for individuals diagnosed with ASD or a related disability. Parents and advocates have rushed to adopt the technology; for example a Google search of "autism and iPad and app" generates over 13 million hits, Autism Speaks lists roughly 400 iPad® applications on their website (and notes that the vast majority of these apps are supported only by anecdotal evidence). The research community responded quickly, generating a sufficient number of studies in this short period to warrant a review. Given that autism treatment has been plagued with unsupported and overhyped "miracle of the month" interventions, this research was extremely important. Now it is time to take a step back and summarize what we know. The literature is in a state of flux; there are not enough studies to justify a meta-analysis, but there is sufficient interest and output to warrant some organization and direction. The purpose of this manuscript is to provide a review of the literature on the use of such technological devices as a SGD. Given that these new and developing technologies depart from traditional SGD, such as the DynaVox in terms of availability and affordability, as well as, depart from SGD, such as the GoTalk Express 32, in terms of technological capabilities, it is clear that a summary of the existing research is justified.

This review will focus on the research community's response to these technological advances, with the aim of summarizing and synthesizing research on the use of tablet based and portable media players as a SGD for individuals diagnosed with ASD or a related developmental disability. An analysis of the research in terms of (a) the acquisition of a mand (request) or functional communication repertoire as the primary dependent measure; (b) acquisition of other verbal operants (e.g., tacting or labeling) as the primary dependent measure; (c) teaching strategies; (d) discrimination training as the primary dependent measure; (e) comparisons to other methods of AAC; and (f) participant device preference. Given that all of the studies in the review used single subject research design methodologies, characteristics of quality single case studies were evaluated using Horner et al. (2005) indicators of quality single case research.

[1] The commercial names for these and other products are used throughout this manuscript for identification purposes, and for general clarity. Our use of the commercial product names herein is neither an explicit nor implicit endorsement of these products.

Method

A systematic search was conducted to identify peer reviewed, empirical studies that evaluated handheld computing devices (i.e., iPad®) and portable multimedia players (i.e., iPod®) as a SGD for individuals diagnosed with ASD or a related disorder (i.e., ID, DD).

Search Strategy

ERIC, ProQuest, PsycINFO, and SAGE journals online were searched using a combination of the following free-text terms with Boolean operators and truncation: *iPod, iPhone, iPad, speech-generating device, voice output communication aid, developmental disability, intellectual disability, autism spectrum disorder or autism, communication, mand, tact, multimedia device,* and *handheld computing device*. The search was limited to English speaking and peer-reviewed journals. Additionally, the search was imitated to articles published between 2007 and 2014. The search occurred during the months of February and March 2014.

Inclusion Criteria

To be included in the review, the study must report data that evaluated the use of handheld computing devices and/or portable multimedia players as a SGD. That is, only articles that investigated the acquisition of a communicative repertoire for individual diagnosed with ASD or a related disability were included in the review. Articles that did not report empirical data were not included. The article must have been published after the year 2007, as this was the first year the iPod® Touch was released and the beginning of the use of SGD on this type of device.

Data Extraction

Studies that were included in the review were summarized based on (a) participant age and diagnosis; (b) target behavior; (c) device and application; (d) intervention procedure; (e) results; and (f) research design. Data extraction was performed by the first author and checked by an independent rater for accuracy. No disagreements on extracted data occurred.

Table 1 Summary of reviewed studies

Study	Number of participants (age; diagnosis)	Target behavior[a]	Device and application	Intervention procedure	Research design	Results	# of quality indicators (Horner et al. 2005)
Kagohara et al. (2010)	1 (17; ASD, ODD, ADHD)	Mand (Request)	iPod Touch Proloqu2Go	5 and 10 s prompt delay	Reversal design	100 % correct responding during intervention phase	6 out of 7 Social validity not measured
van der Meer et al. (2011)	3 (13–23; Intellectual Disability)	Mand	iPod Touch Proloqu2Go	10 s time delay with physical prompting	Multiple baseline across participants design	2 acquired ability to mand; 1 did not after 40 training sessions	6 out of 7 Social validity not measured
Achamadi et al. (2012)	2 (13 and 17; ASD)	Mand; Turn device on, unlock screen, and navigate to application	iPod Touch Proloqu2Go	Least-to-most prompting; differential reinforcement; backward chaining	Multiple baseline across participants design	Acquisition of behavioral chain and mand repertoire for all participants	6 out of 7 Social validity not measured
Kagohara et al. (2012)	2 (13 and 17; ASD)	Tact (Labeling) in response to "What do you see?" and "What is it?"	iPod Touch Proloqu2Go	Least-to-most prompting	Multiple probe design	Both participants acquired the ability to respond to both questions	6 out of 7 Social validity not measured
Flores et al. (2012)	5 (8–11; ASD, ID, and multiple disabilities)	Frequency of mands across SGD and PE	iPad Pick a word	Differential reinforcement	Alternating treatment design	Three participants demonstrated higher frequency with SGD; one with PE	7 out of 7
van der Meer et al. (2012a)	4 (5.5–10; multi-system developmental disorder, down syndrome, congenital myotonic dystrophy)	Mand across SGD and MS	iPod Touch Proloqu2Go	Time-delay prompting, verbal prompting, graduated guidance, and differential reinforcement	Multiple-probe design	Three participants acquired ability to mand using both modalities; one only acquired using SGD; 3 participants demonstrated preference for SGD; One presented no preference	6 out of 7 Social validity not measured
van der Meer et al. (2012b)	4 (6–13; ASD and Angelman)	Mand across SGD, MS, and PE	iPod Touch Proloqu2Go	Verbal prompting, graduated guidance, differential reinforcement	Alternating treatment design	Four acquired the ability to mand with the SGD and PE; 2 acquired using MS; 3 demonstrated preference for SGD; 1 for PE	6 out of 7 Social validity not measured
van der Meer et al. (2012c)	4 (4–11; ASD)	Mand across SGD, MS, and PE	iPod Touch Proloqu2Go	Verbal prompting, time delay, graduated guidance, differential reinforcement	Alternating treatment design	Two participants acquired mand with all devices; 4 participants acquired PE and SGD; 4 participants preferred SGD	6 out of 7 Social Validity not measured
Lorah et al. (2013)	5 (3–5; ASD)	Mand across SGD and PE	iPad Proloqu2Go	Time delay with full physical prompting	Alternating treatment with initial baseline design	SGD produced higher rates of manding for 4 participants; 4 participants demonstrated preference for SGD	6 out of 7 Social validity not measured

Table 1 continued

Study	Number of participants (age; diagnosis)	Target behavior[a]	Device and application	Intervention procedure	Research design	Results	# of quality indicators (Horner et al. 2005)
van der Meer et al. (2013)	2 (10 and 11; ASD and ID)	Mand, greetings, answering yes and no, etiquette across SGD, PE, and MS	iPod Touch Proloqu2Go	Least to most prompting	Alternating treatment with initial baseline design	One participant acquired PE faster and demonstrated preference for SGD; One participant acquired PE only and demonstrated preference for PE	6 out of 7 Social validity not measured
Sigafoos et al. (2013)	2 (4 and 5; ASD)	Mand Reaching aggression (for one participant)	iPad Proloqu2Go	Least-to-most physical prompting	Multiple baseline across participants design with maintenance and generalization phases	Both participants acquired the ability to mand, results maintained and generalized; Decrease in aggression for one participant	6 out of 7 Social validity not measured
Dundon et al. (2013)	1 (5; ASD)	Mand	iPad My choice board and go talk now free	Model, lead, test prompting procedure	Multiple baseline across applications	Acquisition of mand repertoire across both devices	6 out of 7 Social validity not measured
Ward et al. (2013)	1 (5; ASD)	Mand	iPad Go talk now free	Model, lead, test prompting procedure	ABC single case design	Increase in independent responding following training	6 out of 7 Social validity not measured
Strasberger and Ferreri (2014)	4 (5.8–12.11; ASD)	Mand with carrier phrase; respond to "What do you want?" and "What is your name?"	iPod Touch Proloqu2Go	Peer assisted	Multiple baseline across participants	All participants acquired the ability to mand; 3 participants acquired the ability to respond to "What do you want?"; Two participants acquired all target behaviors	7 out of 7
Lorah et al. (2014)	4 (4–6; ASD)	Mand with discrimination training	iPad Proloqu2Go	Within stimulus prompting and fading	Chaining criterion within a multiple probe design	All participants acquired the ability to mand, while discriminating between a progressively more complex field of pictures, up to a field of four pictures	6 out of 7 Social validity not measured
Couper et al. (2014)	9 (4–8; ASD)	Mand across SGD, PE, and MS	iPod Touch and iPad Proloqu2Go	10 s prompt delay, least to most prompting	Alternating treatment design	Five participants acquired ability to mand using all 3 devices; 2 acquired with only the SGD and PE; 2 never met criteria for any device; 8 demonstrated preference for SGD; 1 never demonstrated a preference	6 out of 7 Social validity not measured

Table 1 continued

Study	Number of participants (age; diagnosis)	Target behavior[a]	Device and application	Intervention procedure	Research design	Results	# of quality indicators (Horner et al. 2005)
Achmadi et al. (2014)	4 (4–5; DD)	Mand across MS, PE, SGD	iPod Touch with iMainGo2 speaker and Proloquo2Go	0–10 s prompt delay, graduated guidance	Alternating treatment design	Four participants acquired ability to mand. All four acquired PE mastery. 1 did not reach mastery criteria for MS or SGD, 1 reached mastery criteria for PE and SGD at same rate, 1 reached mastery criteria for PE faster than SGD,1 reached mastery criteria for MS and SGD at the same rate but slower than for PE	6 out of 7 Social validity not measured

[a] Each of the target behaviors described are reported as the original articles define them

Interobserver Agreement

A second observer conducted a literature search using the same parameters as the first observer. Agreement was 100 % across both observers. Additionally there was 100 % agreement in terms of articles that met inclusion criteria and with regard to data extraction.

Results

A total of 17 studies met criteria for inclusion in the review. The studies are summarized in terms of their aim including those that (a) evaluate the use of devices on the acquisition of a mand (requesting) repertoire; (b) studies that evaluate the use of devices on the acquisition of other verbal operants (i.e., tacting or labeling); (c) studies that evaluate teaching discrimination; and (d) comparison studies. These data are presented in Table 1.

Quality Indicators of Single Subject Research

All of the studies in the review used single subject research design methodologies. Thus, the characteristics of quality single-subject research design to identify evidence based best practice taken from Horner et al. (2005) were used to evaluate the quality of the summarized research. The indicators used were taken from seven categories including, description of participants and settings; dependent variable; independent variable; baseline; experimental control/internal validity; external validity; and social validity. As summarized in Table 1, 15 of the 17 studies reviewed received a score of six measures of quality research, with social validity measures not included in the research design. Two studies received a score of seven measures of quality research. On the basis of this measure, it can be concluded that the published studies so far are of high quality.

Studies Investigating the Mand (Requesting) Repertoire

The first study (Kagohara et al. 2010) investigated the use of the iPod Touch® with the application Proloqu2Go as a SGD, in the acquisition of a mand repertoire in a 17-year old boy diagnosed with ASD, obsessive–compulsive disorder (OCD), and attention deficit hyperactivity disorder (ADHD). The study used a reversal design, where in baseline, the participant was given access to edible items non-contingently. During training, a 5-s, time delay procedure was implemented, where the trainers used full-physical prompting to evoke correct responding. Next, a 10-s, time delay procedure was implemented and the

participant reached 100 % independent responding. A return to baseline was then implemented and independent responding decreased to below 30 %. Finally, the 10-s, time delay was implemented and responding returned to 100 % independent. The training procedures were effective for the establishment of a mand repertoire using the iPod Touch® has a SGD.

van der Meer et al. (2011) investigated the use of the iPod Touch® with the application Proloqu2Go as a SGD, in the acquisition of a mand repertoire for two males and one female, aged 13–23 years old. All three participants were diagnosed with a severe ID. A multiple-probe design was used to evaluate the effectiveness of the SGD combined with a 10-s, time delay physical prompting procedure, that initially used errorless prompting for the first three training trials. That is, the first three training trials used a 0-s time delay. Two participants acquired the ability to mand for preferred items (a combination of edible and toys), while the other participant did not acquire the ability to independently mand following 40 training sessions.

Achamadi et al. (2012) investigated the acquisition of a mand repertoire in two males, aged 13 and 17, diagnosed with ASD, using the iPod Touch® and application Proloqu2Go as a SGD. A multiple baseline across participants design was used. A noteworthy variation of this research design is that the participants also acquired the ability to turn on the device, unlock the screen, and navigate to the appropriate application and screen page, prior to manding for an item. The training package involved the use of least-to-most prompting, differential reinforcement, and backwards chaining. The training procedures were effective at teaching the necessary behavioral chain required for both manding and the device navigation.

Sigafoos et al. (2013) investigated the acquisition of a mand repertoire in two boys diagnosed with ASD, who were aged 4 and 5 years old respectively. An iPad®, loaded with the application Proloqu2Go was used as the SGD in this study. The authors used a multiple-baseline design that included a maintenance and generalization phase. The training procedures employed least-to-most physical prompting. Data were collected on independent manding, a reaching response, and for one participant hitting. Both participants acquired the ability to mand for toy play following the training procedures. Additionally, the results maintained and generalized. Finally, the acquisition of manding using the SGD resulted in a collateral decrease in hitting for one participant.

Dundon et al. (2013) investigated the acquisition of a mand repertoire in one male, aged 5 years old, with a diagnosis of ASD. The authors used a multiple-baseline design across two different applications, My Choice Board and Go Talk Now Free, on the iPad® to demonstrate experimental effect. The training procedures involved the use of the model, lead, and test prompting strategy. Data were collected on independent and accurate mands, with the results indicating that the prompting strategy was effective in the acquisition of a mand repertoire using both applications and the iPad® as a SGD.

Ward et al. (2013) also investigated the acquisition of a mand repertoire using the Go Talk Now Free application and iPad® as a SGD, using a model, lead, test prompting strategy. The participant in this study was a 5-year old boy diagnosed with ASD. The study was an ABC single case design that included baseline, training, and independent (baseline two) conditions. Data were collected on frequency of independent requests, with the results indicating an increase in independent request following training and the results maintained during a return to baseline.

Studies Teaching Verbal Behavior Beyond Mands

The first study to look beyond mand training was a two-part study conducted by Kagohara et al. (2012). During study one, the researchers used a multiple-probe across participants design with two males, aged 13 and 17 years old who were taught to tact (label) two-dimensional items when asked both "What do you see?" and "What is it?", using the iPod Touch® and application Proloqu2Go as a SGD and a least-to-most prompting procedure. One participant required three training sessions to reach a criterion of acquisition of 83–100 % independence for both responses. The second participant acquired the ability to independently respond to "What do you see?" at 100 % independence and "What is it?" at 75 % independence after 24 training sessions. During the second study, the same participants were taught to label 18 new pictures, using the verbal cue "What is it?," using the same technology and prompting procedures from study one. Both participants acquired the ability to independently label stimuli at 75 % independence within four training sessions.

Strasberger and Ferreri (2014) investigated the acquisition of additional communicative behaviors used peer assisted communication application to teach four males, aged 5.8–2.11 years old and a diagnosis of ASD, to mand in a complete sentence, respond to the questions "What do you want?", and "What is your name?". The study used the iPod Touch® and application Proloqu2Go as the SGD and a multiple baseline across participants design to evaluate the effectiveness of the training package. All four children acquired the ability to mand in a complete sentence, using the device, three participants acquired the ability to respond to the question "What do you want?" and two participants acquired the ability to respond to the question "What is your name?".

Studies Investigating Discrimination Training

Only one study (Lorah and Parnell 2014) specifically investigated the acquisition of a discrimination repertoire as the primary dependent measure, with the iPad® and application Proloqu2Go as a SGD using a chaining criteria design, within a multiple probe. Four males, aged 4–6 years, diagnosed with ASD were taught, to discriminate between picture symbols. The training procedure consisted of a five-phased procedure that used within stimulus prompts and stimulus fading. As the participants were exposed to progressively more complex fields, mand training was conducted using only stimulus prompting. That is, at no time were response prompts (i.e., physical, verbal, or gestural prompts) used to evoke correct responding. The training procedure was effective for teaching picture symbol discrimination in a field of four picture symbols, to a mastery criterion of 80 % independent responding across two consecutive sessions. Furthermore, the mean number of session required to move through the five phases was 14.5 sessions, with the minimum requirement being 10.

Studies Comparing SGD to Other AAC

Flores et al. (2012) compared the iPad® and application *Pick a Word* as a SGD and a PE, in the acquisition of a mand repertoire in four males aged 8–11 years old. Three of the participants were diagnosed with ASD, one was diagnosed with ID, and one presented multiple disabilities. They used an alternating treatment design, in which a condition was implemented for 3 days and alternated between PE and SGD. Following two alternations, frequency of communication behaviors (i.e., mands) were compared. Three of the four participants demonstrated a higher frequency of independent mands during the SGD condition and one participant demonstrated a higher frequency during the PE condition.

van der Meer et al. (2012a), compared the acquisition of a mand repertoire and participant device preference using the iPod Touch® and application Proloqu2Go as a SGD with MS. The participants included four boys, aged 5.5–10 years old diagnosed with ASD, Multi-System Developmental Disorder, Down syndrome, and Congenital Myotonic Dystrophy, respectively. Using a multiple-probe across subjects design, the participants were taught to mand using verbal prompting, time-delay prompting, graduated guidance, and differential reinforcement. Three participants acquired the ability to mand using both MS and the SGD and one participant only acquired the ability to mand using the SGD. Three participants demonstrated preference for the SGD, while one did not demonstrate a specific preference.

van der Meer et al. (2012b) compared acquisition, maintenance, and device preference using the iPod Touch® and application Proloqu2Go as a SGD, with MS and PE in two males and two females, aged 6–13 years old. Three of the participants were diagnosed with ASD, specifically autism, childhood disintegrative disorder, and pervasive developmental disorder- not otherwise specified, respectively. The fourth participant was diagnosed with Angelman syndrome. To evaluate the different AAC modalities, an alternating treatment design was used. Verbal prompting, time delay prompting, graduated guidance, and differential reinforcement were used during training. All four participants acquired the ability to mand for preferred items using the SGD and PE, while only two participants acquired the ability to mand using all three communication modalities. Three demonstrated a preference for the SGD, while one participant demonstrated preference for PE.

van der Meer et al. (2012c) also compared acquisition and device preference using the iPod Touch® and application Proloqu2Go as a SGD with MS and PE in three males and one female, aged 4–11 years, with a diagnosis of ASD. An alternating treatment design and a training package consisting of verbal prompting, time delay prompting, graduated guidance, and differential reinforcement were used. Two participants acquired the ability to mand using all three modalities, while all four acquired the ability to mand using both PE and SGD. All four participants demonstrated a preference for the SGD.

Lorah et al. (2013) compared the acquisition and preference of PE with the iPad® and application Proloqu2Go as a SGD, in five males, aged 3–5 years, with a diagnosis of ASD. An alternating treatment design and five-second time-delay physical prompting procedure were used to evaluate the communication modalities in terms of frequency of independent mands and device preference. The SGD produced higher rates of independent manding than PE for four of the participants, while PE produced higher rates of manding for one participant. Additionally, four participants demonstrated a clear preference for the SGD with one participant demonstrating a preference for PE.

van der Meer et al. (2013) used an alternating treatment design with baseline, intervention, preference assessment, and follow-up phases to compare the iPod Touch® and Proloqu2Go as a SGD with PE, and MS, in the acquisition of a mand repertoire, acquisition of greetings (e.g., hello), answering yes and no questions, and etiquette (e.g., please) in a 10-year old boy and an 11-year old girl, both of whom were diagnosed with ASD and ID. The training procedures employed a least-to-most prompting hierarchy. For one participant PE was acquired in the 6th training session, MS in the 9th and the SGD in the 12th; however, the participant demonstrated a clear preference for the SGD. For the second participant, PE was acquired after three sessions

and neither the SGD nor MS reached mastery criteria within the context of the study; she demonstrated a clear preference for PE compared to manual sign and the SGD.

Couper et al. (2014) compared MS and PE with the iPod Touch® or iPad® and application Proloqu2Go as a SGD, in nine males aged 4-8, with a diagnosis of ASD, in terms of acquisition rate and device preference. An alternating treatment design and an intervention package that consisted of a 10 s prompt-delay, with least-to-most prompting, were used to evaluate the different modalities of communication. Results indicted that five participants acquired the ability mand using all three methods of AAC, while two participants acquired the ability to mand only using PE and the SGD. Two participants did not acquire a mand repertoire with any of the devices. In terms of device preference, eight participants demonstrated a preference for the SGD device, while one participant presented no preference.

Finally, Achmadi et al. (2014) conducted a study, which investigated the acquisition of manual sign, picture exchange, and the iPod Touch® and application Proloqu2Go as a speech-generating device, for the manding of continued toy play. The participants included four males diagnosed with a developmental disability. An alternating treatment design and a training procedure that consisted of a 0, 3, 5, and 10-s time delay with graduated guidance were used within the research design. Additionally, long-term follow-up data were collected 18-months post intervention. Results indicated that three participants acquired the ability to mand for continued toy play using all three methods, with PE and the SGD occurring at a faster rate than MS. One participant acquired only PE, within the context of the study. During follow-up the participants demonstrated greater maintenance for both PE and the SGD; while demonstrating preference for the SGD.

Discussion

To date, 17 studies evaluated the use of handheld computing devices or portable multimedia players as a SGD, in the acquisition of verbal behavior (communication repertoire) for individuals diagnosed with ASD or a related disability (i.e., ID). All of these studies have specifically used the iPad® hand held computer or the iPod Touch® portable multimedia player. Additionally, the vast majority of these studies, 14 of the 17, have used Proloqu2Go as the SGD application. According to the Horner et al. (2005) criteria, all of the studies are of high quality.

In terms of the verbal operant investigated, 16 of the studies have evaluated the use of the SGD in the acquisition of a mand (requesting) repertoire. Only three studies have investigated beyond manding, specifically evaluating responding to questions and tacting (labeling). One study used the acquisition of discrimination between pictures repertoire as the primary dependent measure, in conjunction with manding. As depicted in Fig. 1, 53 of the 57 total participants (93 %) acquired the ability to communicate using the iPod® or iPad® as a SGD, within the context of the study. With regard to the teaching strategies, a multitude of methods have been used (i.e., physical prompting, time delay prompting, graduated guidance, etc.) with no clear method of instruction emerging as preferred or more effective.

Given the heterogeneous nature of the ASD population and consistency in these data in terms of acquisition and participant device preference (as shown in Fig. 2), the data are compelling. As such, the findings of these studies have clear implications for stakeholders. The overall findings in terms of the acquisition of a mand repertoire and the overall preference for the SGD devices over other options, suggest strongly that stakeholders should consider the use of a handheld computing device or portable multimedia players when addressing the acquisition of verbal behavior.

Comparing AAC

Eight studies have offered a comparison of the iPad® or iPod Touch® as a SGD to other modalities of communication. One study (van der Meer et al. 2012a), with a total of four participants, compared the iPad® or iPod Touch® as a SGD and MS only. Of those four participants, one failed to acquire the use of MS within the context of the study, while all four acquired the ability to mand using the SGD. Additionally, three of the four participants demonstrated a preference for SGD, with one participant presenting no preference. Two studies (Flores et al. 2012; Lorah et al. 2013) compared the iPad® or iPod Touch® as a SGD and PE, with 10 participants, involved in such research. Of those 10 participants, eight demonstrated higher rates of manding with the SGD and two with PE. In terms of device preference, five participants were exposed to a device preference assessment, with four demonstrating a clear preference for the SGD. Five studies (van der Meer et al. 2012b, c, 2013; Couper et al. 2014; Achmadi et al. 2014) have compared the iPad® or iPod Touch® as a SGD with MS and PE, with a total of 23 participants involved in the research. Taken together, 14 participants acquired all three-communication modalities, six acquired only PE and SGD and did not acquire MS, one acquired PE only, and two participants did not acquire the ability to mand with any device within the context of the study. As depicted in Fig. 2, 19 participants involved in this research were exposed to a device preference measure following completion of the training; 16 of the total 19 participants demonstrated a preference for the SGD, one for PE, and two did not present a preference for any device.

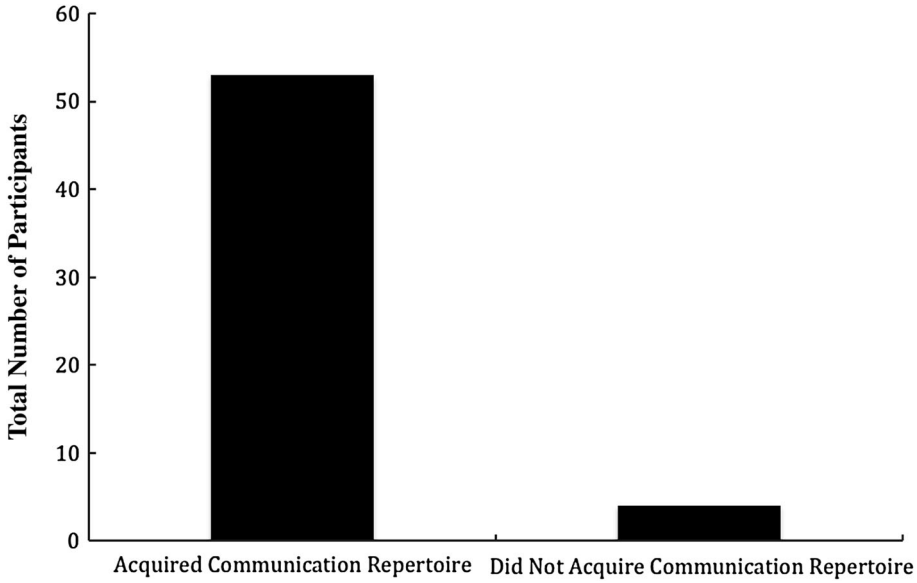

Fig. 1 Acquisition of communication repertoire. Total number of participants who did or did not acquire the trained communication repertoire using the iPad® or iPod Touch® as a SGD, across all 17 studies included in the review

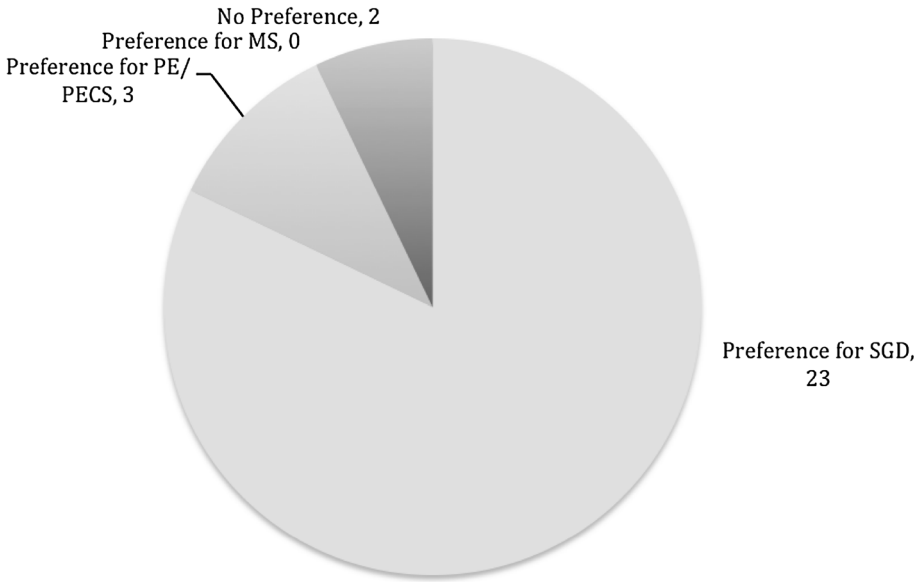

Fig. 2 Participant device preference. Number of participants included in device preference assessments and the demonstrated preference between manual sign, picture exchange or the picture exchange communication system, and the iPad or iPod Touch as a SGD

It is acknowledged that these comparison studies are few and have limitations (Johnston 1988), however they hint at some potentially important extensions. First is the marked preference for the tablet/media player SGD over other AAC. No other SGD devices were compared, so it is not known whether this form of SGD, or SGD in general may be more preferred. The preference may be due entirely to the fact that the SGD used is generally a preferred consumer technology or because children with ASD may respond better to the game-like interface (Tincani and Boutot 2005). Either way, it remains an important finding because technology that is liked will be used, or as Norman (2002, p. 36) observes, "attractive things work better." Simply, a child will be motivated to learn and use a device that is liked; in the case of children with autism, this is not a trivial or inconsequential point. Taking such preference data seriously is also a recognition of the child's rights of autonomy and self-determination. Second results showing that the SGD is as effective as, and often better than other AAC serve as a preliminary proof of concept, which is critical first step in developing a new technology or application. Taken as a whole, these learning and preference data strongly support that contention that tablet based computer or portable multimedia player SGD area promising and preferred means of establishing verbal repertoires in individuals with ASD; or in other words, these devices and their software are not the latest unsupported miracle therapy.

Cautions and Caveats

Although the data summarized are promising, they are also preliminary and should be interpreted as such. To date, no randomized controlled trials (RCT) have been conducted on the topic of handheld computing devices as speech generating devices, thus, additional research is needed to determine if such practices qualify as evidence based best practice. The verbal behavior investigated so far has been limited; 15 of the studies have evaluated the use of the SGD in the acquisition of a mand (requesting) repertoire. Only three studies (Kagohara et al. 2012; Strasberger and Ferreri 2014; van der Meer et al. 2013) have investigated beyond manding, specifically evaluating responding to questions and tacting (labeling). One study (Lorah et al. 2014) investigated the acquisition of discrimination between pictures as the primary dependent measure, in conjunction with manding. Additionally, the only devices used were the iPad® or iPod Touch® and the Proloqu2Go software was used in nearly all studies. All of these results may be constrained by this limited technology. This underscores an important point in this context; the research is not about "iPads® as SGD" but rather is about the combination of hardware, software, and training protocols. All three must work together to provide support for the individuals in these studies. Only the most non-rigorous and superficial would interpret these results as summarizing "iPad® studies."

Future Directions

There is a clear need for additional research on verbal behavior other than the mand (requesting) in this context. Only three studies (Kagohara et al. 2012; Strasberger and Ferreri 2014; van der Meer et al. 2013) have investigated verbal behavior beyond the acquisition of a mand repertoire, both of which offered encouraging results in terms of the use of technology for such acquisition. Given that one of the clear advantages of such technology is its ability to be customized for the speaker and address the full range of verbal behavior, there is an explicit need for such research within the SGD evidence base. Indeed, this may be one of the most compelling advantages of these SGDs over PE/PECS; the potential to grow along with the individual's verbal skills, adding more words, phrases and verbal operants (intraverbals, autoclitics, etc.). Indeed this also points to further research and theoretical advances. As an individual's repertoire grows, issues such as categorizing and classifying multiple icons into meaningful units (i.e. "folders" on a device screen) will come to the forefront, and post-Skinnerian verbal behavior research such as that in stimulus equivalence (e.g., Sigurðardóttir et al. 2012) and Relational Frame Theory (e.g. Hayes et al. 2001; Murphy et al. 2005) will become increasingly important.

Furthermore, the development of improved and new technologies designed for this specific function should become a consideration. Although Apple™ products were innovative in terms of the potential to function as a SGD, other models of handheld computing devices and portable multimedia players are available and should also be used, and software beyond Proloqu2Go should be employed. Further, perhaps the use of Apple™ products in this regard may be discouraged. The iPad® and iPod® may be more difficult to program than Android® or Windows™ devices (Apple products require proprietary Xcode; Android and Windows devices can run apps written in Java). In addition, the restrictions that Apple™ places on the distribution of applications may make it more difficult for researchers or educators to evaluate and develop their own software. Indeed, the software side presents the greatest potential for research and application. Interface design, user interaction, and user experience should come to the forefront. Software allows for interfaces to be designed to meet the particular needs of an individual. In the future perhaps one could design a SGD that not only helps a speaker communicate, but also increases their verbal skills thorough embedded training. The potential for creative collaboration between children with ASD, parents, educators, researchers and developers is one of the most exciting implications of using a tablet based computer or portable multimedia player SGD.

The training protocols used to not only acquire verbal repertoires, but also to manipulate the device (such as Achamadi et al. 2012) require more research and explication. Software or hardware adaptations may be necessary for some users, and these should also be well delineated. Training beyond verbal operants, such as discrimination training (Lorah et al. 2014) should also be a focus of more research.

Beyond the use of SGD and its effects on the verbal repertoires of the individuals who use them, the effects these devices may have on other behaviors and in the individual's social environment should be studied. For example, Sigafoos et al. (2013) showed a decrease in aggression as manding was acquired; certainly functional communication training can result in a decrease of less desirable behaviors, but the effects that SGD have on other behaviors remain an open question. SGD are omni-directional; from a theoretical perspective this feature of SGD should make a large difference, as spoken, face-to-face communication is the least effortful and conveys the most information (Hantula et al. 2011). Verbal behavior acquisition with a SGD would be expected to accelerate curvilinearly over time. Taking this a step further, the effects of SGD on the behavior of teachers and that of a classroom as a whole remain open questions; the changes that may occur when a classroom transitions

from unaided AAC to SGD should be explored. What effects does this have on peer interaction, student teacher interaction and/or teacher behavior? What may happen when an individual goes into the community and uses an SGD in a store or restaurant? What advantages does an off the shelf technology confer to the user, as compared to PE/PECS and MS in the school and community? What are the relative costs involved with using a SGD compared to PE/PECS in terms of staff time (to create cards, icons and books), training time, maintenance of the AAC, acquisition cost? What are the long-term effects regarding a comparison of such hand held devices to PE/PECS? Careful cost/benefit analyses are warranted.

Additional considerations should include the use of such devices beyond the scope of a SGD in terms of simultaneous development of academic and leisure skills. Lastly, the continued replication of this research, including the incorporation of RCT, is needed to increase the generality and validity of the use of handheld computing devices and portable multimedia players as an evidence based best practice in the acquisition of verbal behavior for individuals with ASD or a related disability. However, it is clear that the literature has already moved beyond the basic (but important) question of "do these consumer products work as SGDs?" The answer is a clear affirmative. Now research should not only replicate this finding, but should also incorporate extensions and further analyses into study designs.

Given the compelling results of the articles reviewed within this manuscript it is necessary for this line of research to continue and also to inform not only researchers, but educators and policy makers. The use of portable tablet computers and multimedia players as a SGD has an emerging evidence base. However, it is not solely these devices that make the difference. One must never succumb to the 'hardware happiness hype' and mistake the device for the process. The research reviewed shows clearly that it is device and software and training protocol that makes the difference. That is, the incorporation of evidence based best practice, in terms of teaching procedures such as the use of reinforcement, prompting, and errorless learning (National Autism Center 2009) enhances the use of such devices as a SGD. The hardware alone is not a useful communication tool.

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