A community-based randomized-controlled trial of Speech Generating Devices and the Picture Exchange Communication System for children diagnosed with autism spectrum disorder

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The present study was approved by the research ethics committee at the National University of Ireland, Galway (Ref: 16-Oct-05) and was performed in strict accordance with all associated ethical standards. Consent was obtained from the parents or guardians of all potential participants prior to initial screenings, assessments, and video recordings.

Abstract

A community-based randomized-controlled trial was conducted to compare the effectiveness of Speech Generating Devices (SGD) and the Picture Exchange Communication System (PECS) for improving social and communicative behavior in children diagnosed with autism spectrum disorder (ASD). Thirty-five children with ASD were randomized to high-tech (SGD) or low-tech (PECS) forms of augmentative and alternative communication (AAC). The primary outcome measures of the trial were skills targeted in PECS. Results indicated that both forms of AAC produced significant improvements in communication, and that improvements did not differ significantly different between approaches. These findings support the use of high-tech AAC and highlight the need for an evidence-based protocol for its use as well as evaluation with a range of social and intellectual impairment.

Keywords: autism spectrum disorder, picture exchange communication system, augmentative and alternative communication, technology

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Introduction

Recent estimates indicate that the prevalence of children diagnosed with an autism spectrum disorder (ASD) has increased to approximately 1 in 68 (Centers for Disease Control and Prevention, 2014). Among the challenges faced by this population, individuals with ASD often present with deficits in social and communicative functioning (American Psychiatric Association, 2013). Furthermore, existing research has suggested that 25 to 35% of these individuals will not develop spoken language (Rose, Trembath, Keen, & Paynter, 2016; Tager-Flusberg & Kasari, 2013). Intensive and effective intervention to improve social and communicative functioning has been found to be critical for addressing the needs of this population, as children who do not acquire social and communicative skills in early childhood are at high risk for poorer outcomes later in life (Anderson, Oti, Lord, & Welch, 2009; Harris & Handleman, 2000; Liss et al., 2001; National Research Council, 2001).

Augmentative and Alternative Communication (AAC) systems are commonly introduced to supplement, or establish, social and communicative behaviors in individuals without vocal speech (Mirenda, 2003; Sigafoos et al., 2016). Both aided and unaided versions of AAC exist (Sigafoos et al., 2016), and options for aided AAC include low-tech (i.e., picture cards) and high-tech forms (e.g., electronic devices; Gilroy, McCleery, & Leader, in press; Sigafoos et al., 2016; Still, Rehfeldt, Whelan, May, & Dymond, 2014). Among the low-tech forms of AAC, the Picture Exchange Communication System (PECS) has extensive research support as an intervention for both improving socialization and communication and reducing challenging behaviors in individuals with a range of communication impairments and disabilities (Bondy, 2012; Frost & Bondy, 2002; Tincani & Devis, 2011). The PECS protocol alone has more than 100 publications demonstrating mostly positive outcomes (Bondy, 2012). While the majority of this support is derived from single-case experimental evaluations, several of these positive evaluations have used randomized-controlled clinical trials (Howlin, Gordon, Pasco, Wade, & Charman, 2007; Schreibman & Stahmer, 2014; Yoder & Stone, 2006).

Despite emerging support for the use of electronic Speech Generating Devices (SGD), evaluations of high-tech AAC have been limited in the range of behaviors targeted (Gilroy et al., in press; Lorah, Parnell, Whitby, & Hantula, 2015; McCleery, 2015). Reviews of this literature have found that the literature supporting the use of SGDs to establish social and communicative behavior has focused almost exclusively on short-term acquisition of "requesting behavior" (Gilroy et al., in press; Lorah et al., 2015; Nepo, Tincani, Axelrod, & Meszaros, 2015; Stephenson & Limbrick, 2015). Gilroy and colleagues (in press) systematically reviewed the existing literature on high-tech AAC and found that many of the peer-reviewed studies that targeted "requesting behavior" have focused on contrasting types of requests (e.g., spontaneous requesting versus responding to a question). Additionally, these studies rarely included checks for correspondence (accuracy of communication) and have varied in how "requesting behavior" was taught and shaped (e.g., spontaneous communication first versus answering questions first). Further, only one evaluation of high-tech AAC has used a well-controlled trial and randomized assignment to evaluate communication outcomes (Kasari et al., 2014). Kasari and colleagues (2014) used a well-controlled design and found good support for the use of high-tech AAC in teaching communication skills within a naturalistic communication intervention, though such an approach is not easily compared to traditional function-based communication approaches (e.g., PECS). In particular, the naturalistic communication training approach did not directly target or measure the functional nature of social and communicative behavior (e.g., requests, comments, answering questions), nor whether these behaviors were performed spontaneously or independently. As such, these findings support the use of high-tech AAC in naturalistic communication training but make it difficult to determine how effective SGD-based training would be in a function-based approach that emphasizes independent and spontaneous responding known to be critical for adaptive real-world communicative functioning.

The purpose of the present study was to compare the effectiveness of high-tech (SGD with social/communicative approach) and low-tech (PECS using picture cards) forms of AAC for establishing social and communicative behaviors in children with ASD. Both AAC types (SGD, PECS) were examined and compared using the established teaching sequence in PECS (e.g., Phases I-VI) using a randomized-controlled experimental design, and this trial sought to answer the following questions: 1) are high-tech and low-tech AAC approaches equally effective for establishing independent requesting skills (mand); 2) are high-tech and low-tech AAC approaches equally effective for establishing queried requesting skills (i.e., “what do you want?”; intraverbal-mand); and, 3) are high-tech and low-tech AAC approaches equally effective for establishing queried social responding (i.e., “what do you see?”, “what do you hear?”; intraverbal-tact).

Methods

Design

This community-based randomized-controlled trial was conducted within two schools in a western region of Ireland. Participants were 35 primary school age children diagnosed with ASD who were served in public school settings designed for learners with ASD. Trial participants were randomly assigned to one of two treatment groups—SGD (high-tech) or PECS (low-tech). Treatment groups varied according to the AAC type used, with the PECS group using picture cards and the SGD group using a low-cost electronic speech generating device.

Randomization was conducted at the classroom level to allow for specialized training of staff in a natural educational intervention context and to evenly balance chronological ages and developmental levels across the two treatment groups. All trial participants were provided with communication treatments delivered by trained and supervised graduate students from a university-based Applied Behavior Analysis training program in the school setting. Communication training in the high-tech AAC treatment group targeted the skills defined in Phases I-VI of the PECS teaching protocol and the low-tech AAC treatment group received training as per established PECS procedures. The trial took place in four stages: 1) Initial intake and administration of participant characterization measures; 2) randomization to treatment groups and administration of baseline experimental change measures; 3) delivery of communication training; and 4) administration of post-treatment experimental change measures. Experimental change measures were collected prior to, and following, approximately four months of communication training delivered in the public-school setting.

Study Inclusion Criteria

Participants were eligible for participation so long as they had (1) a formal diagnosis of autism spectrum disorder; (2) impaired communication defined as one or more standard deviations below average on communication subscale of the ABAS-3; (3) difficulties with socialization defined as one or more standard deviations below average on socialization subscale of the ABAS-3; and (4) no other conditions which accounted for their impairments in social or communicative abilities (i.e., intellectual disability [ID], cerebral palsy, Down syndrome). Individuals were screened for autism symptoms and social and communication deficits using standardized measures. Ideal comparisons would have targeted participants who had never been exposed to previous AAC intervention; however, this was not pragmatically possible given the educational policies and practices for individuals with ASD in the school-based setting in Ireland.

Participant Recruitment and Assignment

Schools and autism classrooms were identified from the 2016-2017 report on Special Classes in Primary and Post Primary Schools (National Council for Special Education, 2016). The report identified schools in Ireland that served children with special needs, along with the number of classrooms, levels of staffing, and general student characteristics. From this list, schools were identified if they (1) were location within 30 kilometers of the host university; (2) had at least two classrooms designed specifically for students with autism; and, (3) the autism classrooms served children in the primary school age range. A total of four schools were identified and contacted, and two schools agreed to participate. A total of seven classrooms were included in the study and study participants were randomized at the classroom level using an online randomization tool (Haahr, 1998). An average of 4.38 participants attended each of the classrooms (*SD* = 1.52, *Mdn* = 6, Range = 2-6) and the staffing for all classrooms consisted of one teacher, two special needs classroom assistants, and a maximum of six students. A flowchart of participant recruitment and assignment is presented in Figure 1.

Communication Modality

Participants were provided with training using one of two communication modalities: high-tech AAC (SGD, tablet application) or low-tech AAC (PECS, picture icons). Both AAC types focused on the skills outlined in the PECS teaching sequence (Frost & Bondy, 2002). The PECS teaching sequence centers on teaching and expanding an individual’s use of independent, functional communication. Functional communication skills were taught consistent with Skinner’s analysis of Verbal Behavior (Skinner, 1957). Functional approaches to communication hold that the consequences for behavior determine the nature of the response, rather than the specific form of the response. For example, a child stating “firetruck” may do so to receive a firetruck toy but may also say “firetruck” for some type of general praise (e.g., “Great job! That is a firetruck”). The functional approach permits a consistent comparison of communication in cases when the specific form of communication differs but is functionally the same (e.g., spoken words, picture card exchanges, generated speech). Skinner’s verbal operants were used to measure communication in both high-tech (generated speech) and low-tech (picture exchanges) AAC for independent requests (e.g., AAC mand), queried requests (e.g., AAC intraverbal-mand), and queried social responses (AAC intraverbal-tact).

Picture Exchange Modality. Participants assigned to the PECS group were taught to use picture cards to communicate. Treatment in this condition followed the teaching sequence and procedures outlined in the PECS teaching protocol and participants were provided programming specific to their present level of independent communication, based on the results of their baseline communication assessment. Communication books and sentence strips were constructed and developed consistent with the materials for the PECS teaching protocol (Frost & Bondy, 2002). All picture cards were laminated and sized at 3cm-by-3cm by default and were resized as needed. Picture card images were constructed using the free and open source Mulberry Symbol Set (Paxton, 2015) or from photographs of specific items. Therapists were trained on all components of the PECS procedures prior to delivering therapy and weekly supervision was provided by doctoral-level behavior analysts throughout the trial. Teachers and classroom staff were provided with training prior to treatment, as well, and on-going consultation was delivered as needed.

Speech Generating Device Modality. Participants assigned to the SGD group were taught to use a tablet application to communicate. Teaching in this condition was based on the teaching sequence (e.g., Phases I-VI) and procedures (e.g., error correction, checks for correspondence) outlined in the PECS teaching protocol. The PECS protocol was adapted for use with SGD based on existing extensions of PECS with SGD (King et al., 2014). Participants were provided with programming specific to their present level of independent communication, based on the results of their baseline communication assessment. Trial participants were provided with a 7” Samsung Galaxy ™ tablet device that was preloaded with an AAC application. Tablets were secured with the AAC application permanently pinned to the screen in administrative mode, preventing participants from accessing any other functionality or applications without first re-imaging the device and its drive. A cross-platform SGD application (i.e., Android ™, iOS ™, Windows ™) developed by the first author (Gilroy, 2016) was used with all participants on all devices. Use of the application mirrored that of the traditional PECS tools and materials, modeled from interactions with picture cards and communication books (e.g., selecting icons, manipulating pages, constructing sentence frames). The application accommodated all phases of the PECS protocol, with single-icon approaches suited for early users (e.g., Phase I) and sentence structure being necessary for more advanced users (e.g., Phase IV+). The Mulberry Symbol Set (Paxton, 2015) was included in the application to keep the images and assets consistent across both high-tech and low-tech approaches. Initial icons were sized at 3cm-by-3cm by default and were resized as needed. Consistent with the PECS modality, photographs of specific items could be constructed and resized as necessary. All therapists were trained on all components of the PECS procedures prior to delivering therapy and weekly supervision was provided by doctoral-level behavior analysts throughout the trial. Teachers and classroom staff were provided with training prior to treatment, as well, and on-going consultation was delivered as needed.

Intake and Participant Characterization Measures

Childhood Autism Rating Scale, Second Edition. Autism symptoms were assessed using the Childhood Autism Rating Scale, Second Edition-Standard Form (CARS2-ST). The CARS2-ST is a measure used to assess symptoms of autism and their severity (Schopler, Van Bourgondien, Wellman, & Love, 2010). The CARS2-ST has been found to have strong internal consistency, with Cronbach's alpha estimated to be 0.93 (Vaughan, 2011). Parents and teachers completed the Childhood Autism Rating Scale, Second Edition-Questionnaire for Parents or Caregivers (CARS2-QPC) and the CARS2-ST was scored using information from parents, teachers, and direct observations by study authors. This measure yielded 15 distinct subscales and participants with total scores of 30-36 were indicative of "mild-to-moderate" symptom severity and scores of 37 or greater were indicative of "severe" symptom severity (Schopler et al., 2010). Children rated below a score of 30 were considered having "little-to-no" symptoms of ASD.

Adaptive Behavior Assessment System, Third Edition. Adaptive behavior, including social and communicative functioning, was assessed using the Adaptive Behavior Assessment System, Third Edition (ABAS-3; Harrison & Oakland, 2015). The ABAS-3 provides a measure of the everyday skills and knowledge necessary to function independently in daily life. Measures of adaptive behavior were determined based on teacher and parent report. The ABAS-3 provides measures of an individual's Conceptual, Social, and Practical skills as well as a General Adaptive Composite (GAC), which reflected an individual's overall level of adaptive behavior (Harrison & Oakland, 2015). The ABAS-3 also has specific subscales related to socialization and communication and has been found to have good internal consistency, with Cronbach's alpha ranging 0.96 to 0.99 (Harrison & Oakland, 2015).

Two-Phase Preference Assessment. All study participants received a two-phase preference assessment to empirically determine potential reinforcers. Assessments were administered in multiple phases to increase the accuracy and reliability of preference assessments (Fisher et al., 1992; Fisher, Piazza, Bowman, & Amari, 1996). Preferences were formally assessed prior to structured communication assessments and were updated as necessary. Information regarding preferences was first collected from parents and teachers using the Reinforcer Assessment for Individuals with Severe Disabilities (RAISD; Fisher et al., 1996). The RAISD is a structured interview used with caregivers to gather information related to items and activities that are likely to be preferred by participants. This interview provided an ordered list of stimuli to be used with additional, more formal preference assessments (Fisher et al., 1992; Pace, Ivancic, Edwards, Iwata, & Page, 1985). Participants were administered a Paired Stimulus preference assessment using the ordered list of preferred items on the RAISD (Pace et al., 1985). All individual items were provided to participants for at least 30 seconds prior each preference assessment. From the results of this assessment, the most preferred item identified was selected for use as a potential reinforcer so long as this item was selected in at least 80% of all opportunities. Highly preferred items were necessary prior to baseline communication assessments to confirm that the rates of independent communication were a function of a skill deficit, rather than a motivational deficit.

Dependent / Experimental Change Measures

The primary outcome measures for the study were independent, unprompted, and functional communication based on the verbal operants targeted in the PECS teaching sequence

(Frost & Bondy, 2002). These types of communication were assessed using a structured, live behavioral communication assessment prior to, and following, communication training. A direct behavioral assessment was selected to index the primary outcome measures, as standardized measures can include items that are too advanced for children with ASD and because factors such as motivation and attention can also skew results (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008). All assessments were video recorded in participants' schools and later scored by pairs of trained observers using the BDataPro electronic data collection program (Bullock, Fisher, & Hagopian, 2017). The BDataPro computer program was used by recorders to measure behavior in real-time and to provide measures of inter-observer agreement. The structured communication assessment was designed to index the range of social and communicative behavior targeted in Phases I-VI of the PECS teaching protocol. These assessments were used to assist in quantifying both the range and rates of spontaneous, functional communication demonstrated by participants (e.g., requests, comments, responses to questions). Functional communication skills were assessed through providing analogues to the phases of the PECS protocol (Frost & Bondy, 2002). Using the PECS protocol as a reference, this assessment measured the degree to which trial participants independently demonstrated social and communication behavior targeted in each phase of the PECS teaching sequence.

Independent communication using AAC was assessed from basic (e.g., requests with single option) to more advanced forms of language (e.g., detailed requests with multiple preferred items, social comments and responding). Participants were administered each component of the structured communication assessment, in order, regardless of their level of independence. Assessments were performed by study personnel that were known and familiar to the participant. Participants were provided at least 1 minute of pre-session access to each of the preferred items prior to the assessment to confirm their interest. Independent and correct communication produced 30 seconds of access to the item or activity requested and correct social communication produced brief social praise (e.g., “That was exactly right!”, “Good job!”). No error correction or prompting was delivered during the structured communication assessment. All icons were in color, 3cm by 3cm in size, and all components of the communication assessment were administered until the child demonstrated two responses (correct or incorrect) or until 2 minutes elapsed. The assessment sequence and procedures are outlined below and presented in Figure 2.

Simple AAC Request (Component 1). The initial component of the structured communication assessment entailed a request with a single item on in the visual field (e.g., on book, on screen). The field consisted of a single, highly-preferred item (e.g., puzzle, trains). The mostly highly preferred item was used in this component.

Discriminated AAC Request: Preferred versus Nonpreferred (Component 2). The second component of the structured communication assessment entailed a request with a single highly-preferred item and a single non-preferred item available. The non-preferred item was selected based on teacher report (e.g., difficult tasks, non-preferred assignments). Communication responses that did not correspond with the highly-preferred item were considered incorrect.

Discriminated Request: Preferred versus Preferred (Component 3). The third component of the structured communication assessment entailed a request with two highly-preferred items available. Both items were selected from the results of the earlier preference assessment. Checks for correspondence were provided following each communication response, such that the participant was prompted to take the item they requested from the examiner. Communication responses that did not correspond with the check were considered incorrect.

Request with Sentence Structure (Component 4). In the fourth component of the communication assessment, the communication response entailed constructing a sequence with multiple icons (e.g., sentence structure). This sequence entailed placing icons on a sentence strip for the PECS group and dragging icons into a sentence frame for the SGD group. Correspondence checks continued using the same procedures and conditions as earlier components.

Request with Traveling and Problem-Solving (Component 5). The fifth component of the assessment was identical to the fourth but varied the location of the AAC materials (e.g., book, device). That is, this component required the participant to travel to their AAC materials, approach the communication partner with their AAC materials, and then perform the AAC response. While the traveling component of PECS generally precedes both sentence structure and icon discrimination, traveling and problem-solving was assessed at the highest levels of complexity for spontaneous requests to provide the most conservative estimate of a participant's independence with complex requests (i.e., sentence structure, icon discrimination). All components had to have occurred independently and passed the correspondence check to be considered correct.

Request following Query (Component 6). The sixth component was nearly identical to the fourth, though the response was preceded by a query from the assessor. That is, the assessor stated to the participant, "What do you want?" and indexed whether the participant communicated in response to this query. Consistent with the earlier component, both sentence structure and a successful correspondence check was necessary to consider the response correct (e.g., “I Want”, “Trains”).

Social Communication following Query (Component 7). The seventh and final component was functionally distinct from requesting. In this context, the assessor queried the participant on a topic unrelated to their preferences. For example, the therapist stated, “What do you hear?” prior to playing an animal noise. In this component the participant would need to use sentence structure to correctly respond to the query (e.g., “I Hear”, “Piggy”). Both sentence structure and the accurate referent (e.g., animal referred to) were necessary for the response to be considered correct.

Interobserver Agreement

Interobserver agreement was calculated for standardized and experimental change measures. Structured communication assessments were recorded electronically by pairs of trained observers using the BDataPro data collection software (Bullock et al., 2017). Reliability was calculated for 97.14% of participants (n = 34 of 35) in both pre- and post-treatment communication assessments. Mean overall agreement in pre-test assessments was 98.69% (Range = 94.03-100) and overall agreement in post-test assessments was 97.31% (Range = 93.30-100). Parents of one student did not consent to videotaping and that participant’s communication assessments were rated electronically, in real-time, with only a primary data collector. All standardized assessments were blind scored and double entered to ensure accurate scoring, correct entry, and 100% agreement.

Data Analysis Plan

Repeated measures analyses of variance (ANOVA) were performed to investigate differences in the rates of communication demonstrate following communication training. Time

(Baseline versus Intervention) was included as a within-subjects factor and AAC Type (SGD vs PECS) was included as a between-subjects factor. Individual and combined rates of communication (e.g., mand, intraverbal-mand, intraverbal-tact) were drawn from the behavioral scoring results of structured communication assessments.

Ethical Approval

The present study was approved by the research ethics committee at the National University of Ireland, Galway and was performed in accordance with all associated ethical standards. Consent was obtained from the parents or guardians of all potential participants prior to initial screenings, assessments, and video recordings.

Results

Participant Characteristics

Thirty-five participants participated in the research trial. All participants had independent evaluations by psychologists that confirmed the presence of ASD and ruled out the presence of ID. Average participant age was 8.74 years of age (*SD* = 2.19, *Mdn* = 9, Q_1 = 7, Q_3 = 10) and the percentages of male and female participants were 91.42% (*n* = 32) and 8.58% (*n* = 3), respectively. Participant characteristics are presented in Table 1. Chronological ages were not significantly different for the SGD and PECS groups. Participants demonstrated mild-to-moderate ASD severity overall[1] on the CARS2-ST (*Mean* = 2.31, *SD* = 0.79, *Mdn* = 2.5, Q_1 = 2, Q_3 = 3) and substantial impairments in overall adaptive skills on the GAC of the ABAS-3 (*Mean* = 67.73, *SD* = 10.81, *Mdn* = 6, Q_1 = 61.25, Q_3 = 77). Observed ASD symptoms, overall adaptive skills, and specific impairments in socialization and communication were consistent across the two groups. Similarly, baseline rates of independent and functional AAC use (responses per

[1] CARS2-ST symptom severity was coded as follows: 1= Little-to-no symptoms, 2 = mild-to-moderate symptoms, and 3 = severe symptoms.

minute) were low overall and comparable across the two groups, see Table 2. The results of behavioral and standardized measures confirmed substantial difficulties in social and communicative abilities across all participants in both groups.

Progression in PECS Teaching Protocol

Participants began communication training consistent with their performance on the baseline communication assessment. Initial starting points[2] were comparable for SGD (*Mean* = 1.11, *SD* = 0.47, *Mdn* = 1, Q_1 = 1, Q_3 = 1) and PECS groups (*Mean* = 1, *SD* = 0, *Mdn* = 1, Q_1 = 1, Q_3 = 1). All but one participant began at Phase I, with a single participant in the SGD condition beginning at Phase III-C. Progression through the teaching sequence was similar across both the SGD (*Mean* = 3.55, *SD* = 0.85, *Mdn* = 3, Q_1 = 3, Q_3 = 4) and PECS groups (*Mean* = 3.41, *SD* = 0.80, *Mdn* = 3, Q_1 = 3, Q_3 = 3). No participant in either group had reached the equivalent of Phase VI of the PECS teaching sequence prior to the conclusion of the research trial.

Overall Rates of AAC Communication

A repeated-measures analysis of variance (ANOVA) with Time (Baseline versus Intervention) as a within-subject factor and AAC Type (SGD vs PECS) as a between-subject factor was performed on the combined rates of AAC communication (mand + intraverbal-mand + intraverbal-tact; N35). A significant main effect was observed for Time, whereby combined rates of independent and functional AAC communication increased following intervention relative to baseline, F (1, 33) = 203.336, ηp^2 = .860, p < .001. There was not a significant effect for Type, F (1, 33) = 0.032, ηp^2 = .001, p = .859. A significant interaction between Time and Type was not observed, F (1, 33) = 3.200, ηp^2 = .083, p = .083. The main effect of Time was also

[2] Starting points were coded according to the numbered components of the communication assessment and were related to the PECS teaching sequence as follows: 1 = Phase I, 2 = Phase III-A, 3 = Phase III-B, 4 = Phase IV, 5 = Phase II, 6 = Phase V, and 7 = Phase VI.

observed in individual repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subject factor, separately for PECS, F (1, 16) = 98.685, $\eta p^2 = .860$, $p < .001$, and SGD, F (1, 17) = 107.139, $\eta p^2 = .863$, $p < .001$.

AAC Requesting Skills (Mand)

A repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subjects factor and AAC Type (SGD versus PECS) as a between-subjects factor was performed on rates of AAC requesting (mand; N35). A significant main effect was observed for Time, whereby the rates of independent and functional AAC requesting increased at outcome relative to baseline, F (1, 33) = 262.815, $\eta p^2 = .888$, $p < .001$. There was not a significant effect for Type, F (1, 33) = 0.027, $\eta p^2 = .001$, $p = .871$. A significant interaction between Time and Type was not observed, F (1, 33) = 3.683, $\eta p^2 = .100$, $p = .064$. Follow-up tests for simple main effects for Type at Time 1, F (1, 33) = 2.491, $\eta p^2 = .068$, $p = .124$, and Type at Time 2, F (1, 33) = 1.186, $\eta p^2 = .034$, $p = .284$, were not significant, suggesting that the significant interaction was driven by the overall relationships among Time 1 and Time 2 with intervention type. The effect of Time was also observed in individual repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subject factor, separately for PECS, F (1, 16) = 165.418, $\eta p^2 = .912$, $p < .000$, and SGD, F (1, 17) = 101.881, $\eta p^2 = .857$, $p < .001$.

AAC Queried Requesting Skills (Intraverbal-Mand)

A repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subjects factor and AAC Type (SGD versus PECS) as a between-subjects factor was performed on rates of queried AAC requesting (intraverbal-mand; N35). A significant main effect was observed for Time, with rates of accurate and functional queried AAC requests increasing significantly following intervention compared to baseline, F (1, 33) = 17.926, $\eta p^2 = .352$, $p <$

.001. There was not a significant effect for Type, *F* (1, 33) = 0.078, ηp^2 = .002, *p* = .781. A significant interaction was not observed for Time and Type, *F* (1, 33) = 0.078, ηp^2 = .002, *p* = .781. The effect of Time was also observed in individual repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subject factor, separately for PECS, *F* (1, 33) = 7.130, ηp^2 = .308, *p* = .017, and SGD, *F* (1, 17) = 12.697, ηp^2 = .428, *p* = .002.

AAC Social Communication (Intraverbal-Tact)

A repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subjects factor and Type (SGD versus PECS) as a between-subjects factor was performed on rates of queried AAC social responses (intraverbal-tact; N35). A significant main effect was not observed for Time, with rates of accurate and functional queried social AAC responses not increasing significantly from baseline to post-intervention[3], *F* (1, 33) = 1.139, ηp^2 = .033, *p* = .294. There was also not a significant effect for AAC Type, as rates of queried social AAC responses did not significantly differ for the PECS and SGD groups, *F* (1, 33) = 1.706, ηp^2 = .058, *p* = .162. A significant interaction was not observed for Time and Type, *F* (1, 33) = 2.046, ηp^2 = .058, *p* = .162. Similarly, significant effects were not observed within individual repeated-measures ANOVA with Time (Baseline versus Intervention) as a within-subject factor, separately for PECS, *F* (1, 16) = 2.138, ηp^2 = .118, *p* = .163, or SGD, *F* (1, 17) = 0.112, ηp^2 = .007, *p* = .742.

4. Discussion

This trial was designed to examine the impacts, and relative impacts, of high-tech (tablet application) and low-tech (PECS, picture cards) AAC interventions on the social and

[3] The authors note that no participants advanced far enough in the teaching sequence to where they would have received training specific to this type of responding (e.g., queried social responding, intraverbal-tact). As such, any effects or improvements in this type of behavior would be unexpected.

communicative skills of children with ASD in school-based settings. Trial results indicated that participants in both AAC groups demonstrated significant improvements in their rates of independent, functional communication. While gains were observed overall, this trial posed specific questions related to potential differences in the effectiveness of the two approaches: 1) are high-tech and low-tech AAC equally effective for establishing independent requesting skills (mand); 2) are high-tech and low-tech AAC equally effective for establishing queried requesting skills (intraverbal-mand); and 3) are high-tech and low-tech AAC equally effective for establishing queried social responding (intraverbal-tact).

With respect to the first and second study questions, the results of this trial indicated that both high-tech and low-tech forms of AAC produced significant overall increases in the rates of independent and queried functional requests (mand, intraverbal-mand). Positive impacts on the rates of independent "requesting behavior" are consistent with the established literature for both PECS and SGD. Namely, both approaches have been used extensively to establish "requesting behavior". This trial extended the present literature by directly comparing the two—quantifying any potential differences in their effectiveness for children with ASD. Using randomized assignment, results from this trial indicated that both high-tech and low-tech approaches produced positive impacts on requesting behavior (e.g., mand, intraverbal-mand) and that improvements from the two were not significantly different for the two intervention types. We highlight here that a critical factor in this lack of difference in social and communication outcomes is likely to have been due to the equally comprehensive nature of the SGD and PECS training protocols, including significant overlap in the nature and functions of the social and communicative behaviors targeted.

Beyond indicating preferences, to address the third study question we evaluated the effectiveness of high-tech and low-tech AAC to increase more general forms of social communication unrelated to preferences (e.g., answering questions). Results from this trial indicated that both high-tech and low-tech approaches did not produce significant increases in queried social responses (e.g., intraverbal-tact). While positive impact was not observed at second observation, it is likely premature to conclude that these participants would not demonstrate this form of behavior with additional exposure to treatment. This is especially important to note, as all trial participants were still advancing towards this stage of treatment (Phase IV) but had not yet reached it.

Next Steps and Future Directions

The results of this trial extend the literature on AAC but highlight several areas in need of additional study. First and foremost, there is a pressing need for a consistent protocol for high-tech AAC. That is, both researchers and practitioners would benefit from an established, comprehensive communication training protocol for SGD-based AAC training that begins with the basic forms of communication (e.g., spontaneous request, mand) and progresses systematically towards more social forms of communication (e.g., queried social responses, intraverbal-tact). A vetted and evidence-based protocol for using, and teaching to use, high-tech AAC would address the varying, and often disjointed, collection of works that have supported the use of SGD in both the research literature and clinical/educational practice thus far. Building from the first need, future evaluations of high-tech AAC require more long-term evaluation regarding the social outcomes of high-tech AAC. The results of this trial speak to this need, as short-term evaluations of high-tech AAC are unlikely to fully capture the full progression from basic operants to more advanced and complex social behavior.

Beyond the need for a comprehensive teaching protocol for high-tech AAC, and a more long-term evaluation of its effectiveness, additional research is needed to better understand how children with more severe impairments might fare with these newer and more complex approaches. It is entirely possible that the positive impacts observed with high-tech AAC in this trial may not be observed if children and adults with more substantial impairments cannot be taught to effectively problem-solve the additional complexities that present during the use of high-tech AAC (e.g., managing volume, battery, weight). As such, additional research with children and adults with other related, and potentially comorbid, disorders (e.g., ID, genetic conditions, severe challenging behavior) is warranted.

Summary

This trial observed that newer, more high-tech forms of AAC were as effective as older, low-tech forms of AAC, for improving the social and communicative behavior of children with ASD. These findings contribute to a growing base of research that supports the use of high-tech AAC as evidence-based practice. Additionally, the results of this trial highlighted several areas that warrant additional investigation before high-tech forms AAC can be considered a completely equal alternative to older, low-tech forms of AAC. Building from these findings, several expansions of this trial have been proposed to answer questions related to the range of skills targeted and levels of disability. First, the present intervention trial will be extended by one full year to more conclusively answer questions related to the later, and more advanced, forms of communication associated with the final stages of the PECS teaching protocol (i.e., Phase VI). Additionally, long-term study of these two approaches could reveal potential differences when communication scenarios require greater detail and specificity to perform (e.g., descriptors). Second, a follow-up trial will be initiated which includes children demonstrating greater levels of intellectual impairment. That is, the same procedures and comparisons will be replicated when children present with both ASD and comorbid ID. Through additional replication and analyses, the results of these community-based clinical/educational trials will serve to answer lingering questions related to which types of approaches are best suited to teach and support individuals with ASD and other related disorders.

Conflict of Interest:

The authors declare that they have no conflict of interest. The mobile application referenced in this work has been released free of charge under the General Public License, Version 3.0. This grants users free access to use, build, and modify the work to suit their own needs, provided that they extend the same privileges to others with their derivative work.

Appendix:

The AAC application used in communication training for this trial is freely available on the corresponding author's public Git, located at https://github.com/miyamot0/FastTalker in source code form. It is a cross-platform, open-sourced project (General Public License-Version 3.0), written in the C# programming language. It will compile and run for devices using the Android ™, iOS ™, and Windows ™ operating systems and users are permitted to freely use, modify, and reverse-engineer the application so long as any derivative works extend the same rights to others. Examples and samples of functionality can be viewed on the corresponding authors Github page, provided at the location above.

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Table 1

Means and Deviations for Descriptive Measures

	SGD			PECS		
Demographic	*Mean*	*SD*	Q_1-Q_3	*Mean*	*SD*	Q_1-Q_3
Age	8.72	1.74	7.25-10	8.88	2.64	7-11
CARS2-ST						
Raw Score	38.31	7.67	31.25-44.5	37.32	9.74	31-47.5
T-Score	50.11	9.72	40.5-58.25	48.88	12.02	40-62
Severity Score*	2.39	0.78	2-3	2.24	0.83	2-3
ABAS-3						
GAC	68.35	19.11	58.25-77	67.11	11.31	61-75
Conceptual	68.00	19.57	56.75-74.25	66.76	10.92	57-75
Social	71.88	19.17	64-79.25	71.76	11.34	63-80
Practical	71.00	20.02	63-80	69.17	11.63	63-77
Communication**	3.55	2.43	1.25-6	3.59	2.5	1-6
Socialization**	4.22	2.60	2.25-5.75	4.29	2.66	2-6

Note. PECS = Picture Exchange Communication System; SGD = Speech Generating Device; CARS2-ST = Childhood Autism Rating Scale, Second Edition-Standard Form; ABAS-3 = Adaptive Behavior Assessment System, Third Edition, SS = 100; * Low-to-minimal symptoms = 1, mild-to-moderate symptoms = 2, severe symptoms = 3; ** = individual subscale, SS = 10.

Table 2

Outcomes of Communication Training for PECS and SGD

	Baseline Change Measures					Post-treatment Change Measures				
SGD	*Mean*	*SD*	Q_1	*Mdn*	Q_3	*Mean*	*SD*	Q_1	*Mdn*	Q_3
Mand	0.14	0.22	0.00	0.00	0.25	0.78	0.27	0.67	0.79	0.89
Intraverbal-Mand	0.00	0.00	0.00	0.00	0.00	0.11	0.13	0.00	0.07	0.19
Intraverbal-Tact	0.01	0.04	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
Combined	0.15	0.25	0.00	0.00	0.25	1.02	0.36	0.71	0.99	1.25
PECS										
Mand	0.04	0.13	0.00	0.00	0.00	0.85	0.22	0.68	0.75	1.03
Intraverbal-Mand	0.00	0.00	0.00	0.00	0.00	0.12	0.18	0.00	0.00	0.17
Intraverbal-Tact	0.01	0.05	0.00	0.00	0.00	0.03	0.06	0.00	0.00	0.00
Combined	0.06	0.17	0.00	0.00	0.00	1.02	0.38	0.96	0.71	1.28

Note. Rates were constructed as responses per minute.

Figure 1. Participant recruitment and assignment

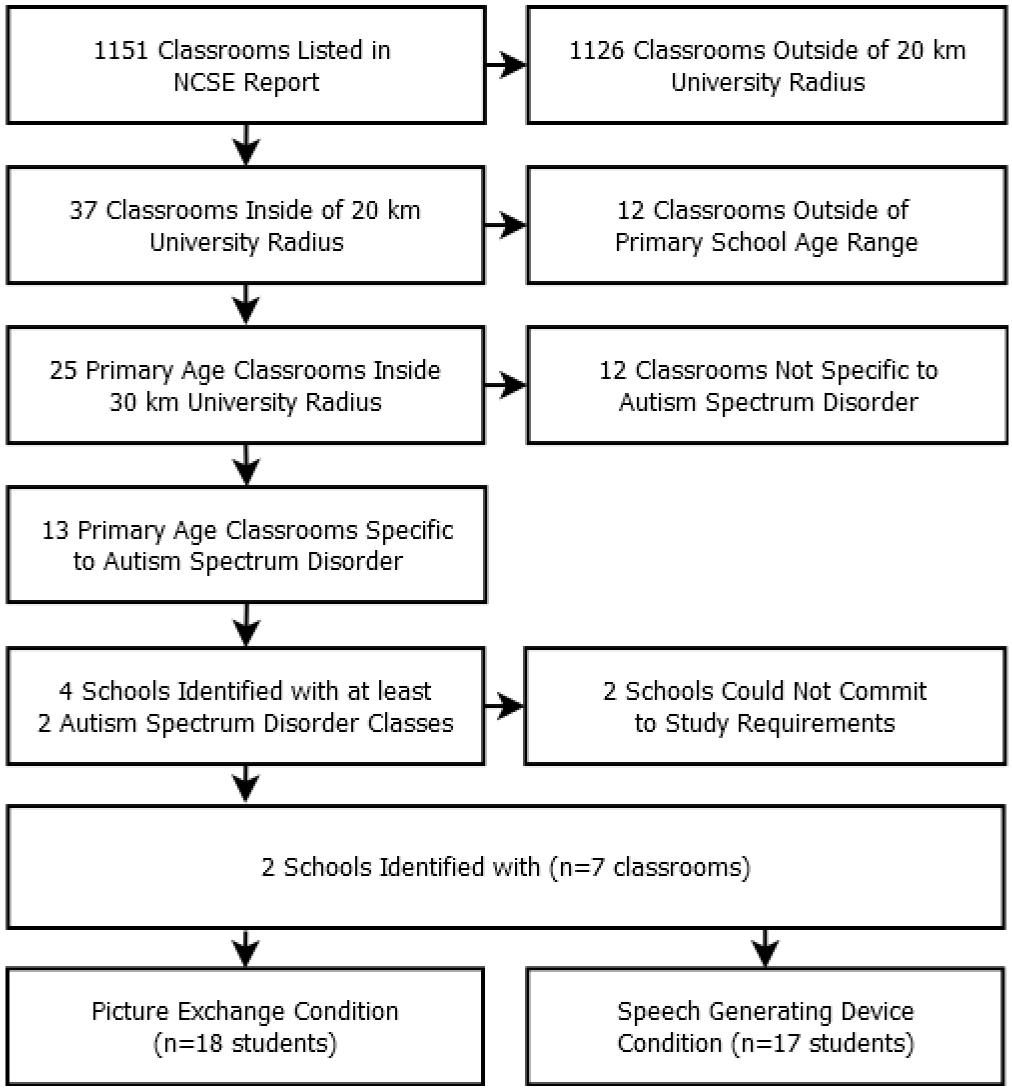

Figure 2. Structured Communication Assessment