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REVIEW PAPER

Systematic Review of Methods for Teaching Social and Communicative Behavior with High-Tech Augmentative and Alternative Communication Modalities

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Abstract A systematic review was conducted to analyze the scope and breadth of the existing training protocols for establishing social and communicative behavior using high-tech, touchscreen devices. This review aimed to determine the degree to which studies evaluating high-tech communication aides have established procedures to extend, or completely replace, traditional low-tech communication training methods (e.g., Picture Exchange Communication System). Individual studies were evaluated based on the range of social and communicative skills targeted. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology was utilized (Prospero: No. CRD42017055541) and systematic searches included the Scopus, PsycINFO, ScienceDirect, and SpringerLink databases. Studies were included in the review if their methods utilized high-tech devices as a vehicle for establishing social and/or communicative behavior. Single-case and group-design studies including children and adults were included in the review if participants were diagnosed with either autism spectrum disorder and/or other developmental disabilities. Fifty-six studies were included and the results of this review indicated that the existing support for high-tech communication aides has focused predominantly on a narrow band of social and communicative behavior (e.g., requesting) and that substantial research is warranted for establishing more advanced forms of social behavior, beyond requesting alone, using these new high-tech methods.

Keywords Autism · Technology · Communication · Socialization · Evidence-based practice

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The prevalence of children diagnosed with an autism spectrum disorder (ASD) has risen over the past several decades (Centers for Disease Control and Prevention 2014). Among the symptoms of this disorder, as with many related developmental disabilities, social, and communicative skills are core deficits (American Psychiatric Association 2013). Recent estimates suggest that roughly 30% of individuals diagnosed with ASD fail to develop spoken language (Tager-Flusberg and Kasari 2013) and many will rely on a range of pre-linguistic (i.e., gaze, reaching) or less effective and less desirable, but functionally equivalent behaviors (e.g., challenging behaviors) to gain access to their wants and needs (Bondy, Tincani, & Frost 2004; Carr & Durand 1985). Individuals diagnosed with ASD often remain non-vocal until they are provided with intensive communication training (Tager-Flusberg and Kasari 2013). Early, intensive, and effective intervention for communication is crucial because those children who fail to acquire social and communicative skills in early childhood are also likely to have poorer intellectual and adaptive outcomes overall (Anderson et al. 2009).

Many genetic disorders and syndromes also manifest ASD-like symptoms and require intensive communication training and behavior management as well (Moss and Howlin 2009). Children and adults with syndromes that include Fragile X, Tuberous Sclerosis, Rett, Down, Phenylketonuria, CHARGE (Coloboma, Heart, Atresia choana, Growth Retardation and Ear abnormalities), Angelman, Neurofibromatosis, Joubert, Williams, Goldenhar, Hyper melanosis of Ito, Noon, Sotos, Velocardiofacial (VCF), Leber's amaurosis, Cohen, Cornelia de Lange, Ehler-Danlos, Lujan-Fryns, and Moebius display degrees of ASD-like impairments and the treatments for these symptoms typically warrant educational and behavioral interventions consistent with those designed for ASD (Moss and Howlin 2009). Among the ASD-like symptoms associated with these conditions, these children and adults often demonstrate impairments in both communication (i.e., delayed speech, minimal speech, totally non-verbal) and social-communicative behavior (e.g., joint attention, eye contact; Sigafoos and Drasgow 2001; Siller and Sigman 2002). Consistent with challenges in ASD, children and adults with these ranging disorders often utilize less adaptive and desirable forms of behavior (e.g., challenging behavior) to gain access to their wants and needs as well if they have not acquired effective communication skills (Bondy et al. 2004).

Augmentative and Alternative Communication (AAC) is used often to either enhance or establish social and communicative behavior for children and adults without vocal speech (e.g., intellectual disability, ASD; Mirenda 2003). Options for AAC span from low-tech (i.e., picture exchange, manual sign) to high-tech forms (i.e., speech-generating devices; Nepo et al. 2015). Among the low-tech forms, the Picture Exchange Communication System (PECS) has extensive support as an intervention for improving communication and socialization, and reducing challenging behaviors, in individuals with a range of communication impairments and disabilities (Tincani and Devis 2011). Recent estimates have indicated that the PECS protocol has well over 100 publications that have demonstrated positive outcomes (Bondy 2012). An emerging body of research suggests that high-tech forms of AAC show promise for improving communication skills as well. Recent reviews on the use of high-tech AAC (i.e., touchscreen devices, media players) as an approach to treating communication disorders have indicated positive outcomes as well, most notably for teaching “requesting behavior” (Kagohara et al. 2013; Nepo et al. 2015; Rispoli, Franco, van der Meer, Lang, & Camargo 2010; Stephenson & Limbrick 2015; Still, May, Rehfeldt, Whelan, & Dymond 2015).

High-tech AAC is an increasingly researched topic in the treatment of communication disorders and ASD (Nepo et al. 2015; Rispoli et al. 2010). Rapidly improving capabilities of both touchscreen devices and individual mobile applications have increased both the availability and affordability of mobile devices suitable for AAC purposes. Whereas commercially available AAC products have historically cost as much as 8000 USD (Lorah et al. 2015b), newer forms of mobile technology cost as little as 49 USD (e.g., Amazon Fire Tablet™). Beyond lowered costs to acquire and access this technology, recent research has suggested that individuals with ASD may prefer to interact with high-tech devices (e.g., tablets, media players) rather than traditional, low-tech equivalents (e.g., picture cards; Achmadi et al. 2014; Lorah 2016). Additionally, some have suggested that high-tech devices themselves may also be perceived as less stigmatizing than low-tech forms of AAC (Lorah et al. 2014; Stephenson and Limbrick 2015).

Despite growing support for, and early adoption of, high-tech AAC in the treatment of communication deficits, fewer studies that have explored communication training beyond initial requests (Lancioni et al. 2007; Still et al. 2014). Reviews on this topic have found that over 50% of studies using speech-generating devices (SGD; including Micro Switches) have focused on a requesting repertoire (Rispoli et al. 2010). A more recent review by Lorah et al. (2015a) found that over 80% of studies using high-tech devices (e.g., touchscreen devices) as an SGD focused exclusively on the mand (e.g., requesting; n = 14 of 17 studies; 82.35%). While it has been suggested that there is strong evidence that high-tech approaches have been effective for establishing a mand repertoire (e.g., requesting access to a preferred item or activity), the evidence base for using high-tech alternatives to establish more advanced and social forms of communication (i.e., responding to questions/intraverbal-mand, answering social questions/intraverbal-tact) remains relatively less examined or explored (Kagohara et al. 2013; Lorah et al. 2015a; Rispoli et al. 2010; Stephenson and Limbrick 2015). In contrast to these newer, high-tech approaches, low-tech approaches such as the PECS protocol have been used extensively to establish a range of social and communicative behavior found to be critical for effective, functional, and robust communication for individuals with autism and other related developmental disorders (Bondy 2012; Bondy and Frost 1994).

The PECS protocol includes a systematic training sequence that builds from basic forms of communication (e.g., a single request possible) to more advanced (e.g., many requests available) and varied forms of communication (e.g., answering questions, commenting; Bondy and Frost 1994). Briefly, the initial stages of PECS focus on establishing the learner's ability to communicate for preferred items and activities. The initial stage (Phase I) is dedicated to teaching the learner to make a request using a single picture card to produce access to a known, highly preferred item. The second stage (Phase II) builds upon the first, preparing the learner to use picture exchange communication skills flexibly in a range of dynamic situations (e.g., traveling to book, collecting the book, traveling to partner) and continues throughout the process. Building from Phase II, the third component (Phase III) is dedicated to preparing the learner to correctly indicate their desires to others when multiple options are present (e.g., several cards, matching requests to actual desires/needs). Subsequent teaching (Phase IV) builds structure into the communication response. For example, communication training in Phase IV may take the form of an exchange consisting of “I want” and “ball”. This stage enhances the communication response, adding additional components to provide context to the listener (e.g., “I see, Ball” vs. “I want, Ball”). Following the addition of sentence structure, the following stage (Phase V) teaches the learner to respond to questions of others related to their preference (e.g., "What do you want to eat?" and "I want, *chocolate.*") and the terminal stage (Phase VI) focuses on teaching the learner to respond to questions that are more social in nature and less related to preferences (e.g., "What do you see?", "What letter is this?"). While not a formal phase in and of itself, the PECS protocol also includes an expansion of sentence structure to include adjectives and descriptors as well, enhancing the learner's ability to more clearly articulate their responses. Using this established training sequence, the learner is taught to use a wide range critical communication skills in a clear, coherent, and developmental teaching sequence that begins with requesting and leads to more advanced and social forms of communication.

The focus of the current review is to systematically evaluate the critical aspects of communication which newer high-tech AAC approaches have and have not been examined. Using the established components of the PECS protocol as a reference for targeted communication skills, this review identifies and examines appropriate studies in order to determine the nature, scope, and breadth of communication skills targeted in each individual study. This review adds critically to the available literature by assessing the degree to which the present literature on high-tech AAC has taken steps to examine, address, and adapt long-standing communication intervention principles and practices established in the low-tech AAC arena. Specifically, the current review seeks to answer the following questions. First, to what extent have studies of high-tech AAC alternatives (e.g., touchscreen, speech-generating devices) to low-tech AAC (i.e., picture exchange) been evaluated within all core phases/components of the PECS training program? Second, to what degree has research on high-tech AAC elucidated and examined procedures for teaching the mand (e.g., requests), the intraverbal-mand (e.g., answering questions related to desired items), and the intraverbal-tact (e.g., answering questions related to naming, labeling) using high-tech AAC? The ultimate aim of this review is to identify gaps in critical aspects and components of high-tech AAC research and practice, and to thereby provide a data-focused framework for future directions and developments aimed at solidifying and improving high-tech AAC communication intervention in the near future.

Method

Literature Search Methods

A systematic search of publications investigating the use of high-tech (e.g., touchscreen, speech-generating) AAC training approaches was conducted. Methods were consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. The databases searched included Scopus, PsycINFO, ScienceDirect, and SpringerLink. The following keywords were provided for all database searches with Boolean operators and truncation: (1) "communication", (2) "training", (3) "autis*", (4) "disabilit*", and (5) "speech generating." Additionally, reference lists for included studies were surveyed and incorporated into the review if they met the criteria for inclusion. Following initial searches and reviews of reference lists, hand searches were conducted for each of the journals identified throughout the search to identify suitable studies currently in press and not yet indexed in the above databases.

Study Selection

The first author reviewed titles and abstracts from the results of keyword searches in all databases and from the search results determined if articles were relevant to the research questions (e.g., included technology, targeted communication skills). Full-text articles were retrieved for all potentially relevant studies and study participants and methods were reviewed before determining if the study met criteria for inclusion. All search procedures were repeated by the second author to ensure that search results were screened reliably and objectively. Disagreements were resolved through discussions related to the inclusion criteria until agreement on inclusion and exclusion was met. The initial search results for Scopus, PsychINFO, ScienceDirect, and SpringerLink databases from the period between September and November 2016 were 182, 171, 461, and 693, respectively.

Criteria for Study Inclusion

Both single-case and group-design research designs were included in systematic searches so long as full-text manuscripts were available. A range of research designs were included so long as they were published in peer-reviewed journals and provided in the English language. Studies that evaluated high-tech forms of AAC (e.g., touchscreen devices) as a singular or a comparative treatment (e.g., high-tech AAC vs. picture exchange) to teach communication skills to children or adults with disabilities (e.g., ID, ASD) were included in the search. Only speech-generating devices with a touchscreen interface were included in the study. There were no constraints on specific device-types, sizes, models, or operating systems, so long as the interface utilized a touchscreen. Micro switch and single-button approaches were considered distinct from that of touchscreen devices, as they did not possess touchscreen capabilities nor the functionality they afford (i.e., multiple icons/panels for discrimination training, ability to move icons dynamically, potential for sentence structure) and were not included.

Types of Outcome Measures

Research outcomes related to the acquisition of communication skills (e.g., requests, responses to questions) using high-tech AAC was a criterion for inclusion. Individual study methods and procedures were coded as they aligned with the training components (e.g., Phases) of the PECS protocol. Studies using high-tech AAC were scored to assess the range and breadth of social and communication skills included in their teaching sequences and methods evaluated, with respect to the established components of PECS. More specifically, studies were assessed and coded to determine if they had addressed one or more of the following skills: a basic request (i.e., Phase I; mand), an environmental traveling or environmental problem-solving component (i.e., Phase II), discriminated requesting (i.e., Phase IIIa/IIIb; mand), requesting including sentence structure (i.e., Phase IV; mand), answering questions related to wants and needs (i.e., Phase V; intraverbal-mand), and answering questions in social and/or academic contexts (i.e., Phase VI; intraverbal-tact). Additionally, while not a numbered phase of the PECS protocol, individual studies were coded if they included a component specific to the utilization of adjectives and descriptors. Data on the individual teaching procedures and targeted skills were as described in the methods section of individual published works.

Reliability and Inter-Observer Agreement

Individual studies included in the search were scored by the first and second authors, independently. Studies meeting criteria for inclusion were scored based on the social and communication skills targeted in the study. Study information was extracted using a checklist that included (1) “Does the study meet inclusion criteria?”, (2) “Were Phase I skills targeted?”, (3) “Were Phase II skills targeted?”, (4) “Were Phase IIIa skills targeted?”, (5) “Were Phase IIIb skills targeted?”, (6) “Were Phase IV skills targeted?”, (7) “Were Phase V skills targeted?”, (8) “Were Phase VI skills targeted?”, and (9) “Were adjectives targeted?”. Checklists were completed during independent reviews of each study and its methodology by the first and second authors. Following independent scoring, disagreements were addressed and resolved through discussions between the study authors until a consensus was achieved.

Results

Fifty-six studies focusing on high-tech AAC were included in this review. Of the 1447 studies within the initial search, 92.61% (n = 1340) did not address communication skills or did not use high-tech forms of AAC to establish a communication repertoire. Within the 107 studies that met inclusion criteria, 50.40% (n = 55) were duplicate results and 15.89% (n = 17) were review studies (i.e., summative reports, no direct evaluation), yielding 35 individual studies. Surveys of reference lists within review studies and hand searches of all included journals yielded 21 additional studies, increasing the total count to 56 included studies (see Fig. 1). Studies were coded individually and the range of coded communication skills (e.g., PECS phases) were scored as being present or not present as denoted by an “*” or a blank space, respectively. The individual components evaluated within included studies are indicated in Table 1, illustrated in Fig. 2, and also summarized below.

Independent Requesting (Mand; Phases I, III, and IV)

Of the 56 studies included in the review, 52 studies (92.86%) included one or more aspects of requesting (i.e., Phase I, Phase IIIa/b, or Phase IV). A total of 11 studies (19.64%) included Phase I skills alone, 34 studies (60.71%) included Phase I and Phase III skills, and 7 studies (12.5%) included Phase I, Phase III, and Phase IV skills. Phase I components were considered to be using a single touchscreen area (e.g., icon) to produce access to a preferred item or event (e.g., “cookie”, “train”). Phase III components were identical to Phase I, with the addition of either nonpreferred or preferred options in the visual field to facilitate discrimination among icons. Phase IV was consistent with Phase III, with the added requirement that sentence structure (e.g., “I want”, “cookie”) be present to honor the request. Studies that utilized a single icon to emit a full, preset sentence (e.g., “I want cookie”) were considered Phase I procedures, as the user did not need to demonstrate discrimination between visual icons nor construct sentence structure. Finally, for the studies that used high-tech SGD’s to establish requesting skills, the mean number of PECS phase equivalents related to requesting was 1.92 (range = 1–3).

Studies including teaching sequences specific to the mand varied significantly with respect to icon-discrimination procedures and the inclusion of correspondence checks. Of the 52 studies targeting the mand (i.e., not the intraverbal-mand), 21 of these studies included icon-discrimination procedures. Within this group, 6 studies (28.57%) included nonpreferred-preferred discriminations alone, 13 studies (61.9%) included preferred-preferred discriminations alone, and 2 studies included both procedures (9.52%). Among these, only eight studies (38.09%) included checks for correspondence.

Responding to Questions (Intraverbal-mand; Phase V)

Within the 56 publications included in this review, 25 studies (44.64%) included procedures that targeted responding to questions as it related to accessing preferred items and events.

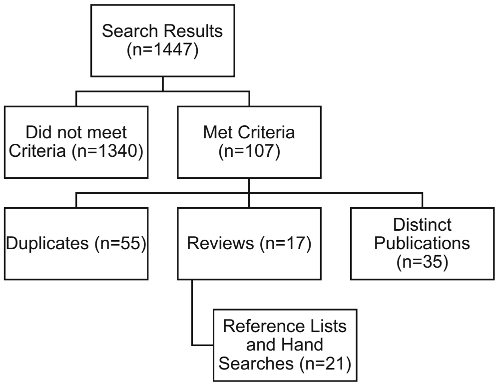

Fig. 1 Systematic review categorization

These procedures focused on responding to adult questions (e.g., "What do you want?", "What do you need?"). This type of responding was distinct from that of responding to adult questions that occurred as part of error correction procedures (e.g., "No, you want 'X'. What do you want?"). Of the studies identified as measuring Phase V skills, the average number of mand-related phases (Phases I, III, IV, and V) completed was 2.92 (range = 1–4).

Individual studies varied with respect to whether they included specific components such as sentence structure and icon discrimination (i.e., nonpreferred-preferred, preferred-preferred) when responding to queries. In the 25 studies that included the intraverbal-mand in their teaching sequence, most studies (n = 20; 80%) included an icon discrimination component. Of these 20 studies, two included nonpreferred-preferred discriminations (10%), 13 included preferred-preferred discriminations (65%), and 6 studies included both components (30%). Within studies that included icon discrimination, only several (n = 4; 16%) included correspondence checks.

Social Communication, Label, or Naming (Intraverbal-tact; Phase VI)

Of the studies meeting inclusion criteria, six studies (10.71%) explored communication skills analogous to those targeted in Phase VI of the PECS protocol. This included social and communication skills that targeted labeling and naming (i.e., "I have …", "I see …") in response to questions. This form of responding was distinct from that of responding to error correction procedures (e.g., "No, that is 'X'. What do you see?"). Of the six studies examining naming and labeling skills, four of these taught these skills in isolation (i.e., apart from other verbal operants).

Distance, Persistence, and Problem-Solving (Phase II)

Skills related to Phase II of the PECS protocol address persistence of communication in the presence of some barrier or obstacle (e.g., distant listeners, device not immediately reachable). Of the 56 studies reviewed, 9 studies (16.07%) included procedures that specifically targeted distance, persistence, or problem-solving skills. These studies interpreted persistence to include either traveling to and/or activation of the device. Of these studies addressing Phase II skills, two studies included Phases I–II (22.22%), three studies included Phases I–III (33.33%), one study included Phases I–III and V (11.11%), one study included Phases I–IV (11.11%), and two studies included all six Phase equivalents (22.22%).

Adjectives and Advanced Vocabulary

Training including adjectives and descriptors exist as a separate, but distinct, component of the PECS protocol. These procedures exist as components parallel to that of the individual phases of PECS and are dedicated to increasing the specificity and versatility of communication (e.g., "I want *chocolate-chip* cookie" vs. "I want *oatmeal-raisin* cookie"). Within the 56 studies included in the review, one study (1.79%) included procedures using descriptors (e.g., color, size) to enhance either a request or comment (e.g., "I see *red* truck").

Breadth of Phases Evaluated

The studies included in the review investigated various forms of communication skills (e.g., PECS target skills, individual verbal operants) to varying degrees. With respect to the breadth of communication skills evaluated, as compared to the complete PECS protocol, eight studies evaluated a single PECS phase equivalent (14.29%), 21 studies evaluated 2 PECS phase equivalents (37.5%), 21 studies evaluated 3 PECS phase equivalents (39.29%), 3 studies evaluated 4 PECS phase equivalents (5.36%), and 2 studies evaluated 6 PECS phase equivalents (3.57%), as indicated in Fig. 3. No studies included a total of five PECS phase equivalents. When interpreted in terms of functional operants underpinning the PECS phases (i.e., mand, intraverbal-mand, intraverbal-tact), 31 studies (55.35%) investigated a single operant, 23 studies (41.07%) investigated 2 operants, and 2 studies (3.57%) investigated 3 operants, as illustrated in Fig. 4.

Clinical Populations

Communication training was provided to a range of clinical populations in the studies identified, see Table 2. A total of 226 (M = 4.03; range = 1–63) children and adults participated in the included studies. Among the populations included, individuals diagnosed with ASD or ID were the most represented overall (ASD: 84.07%, ID: 26.11%). Additional syndromes and condition beyond ASD and ID included Angelman Syndrome (n = 1; 0.44%), Cerebral Palsy (n = 9;

Table 1 Systematic review of speech-generating devices and the picture exchange communication system phase equivalents evaluated

Authors	Year	Title	PECS phase equivalents included					
			I	II	III	IV	V	VI
Schepis, M. M., & Reid, D. H.	1995	Effects of a voice output communication aid on interactions between support personnel and an individual with multiple disabilities.	*		*			
Schepis, M. M., Reid, D. H., Behrmann, M. M., & Sutton, K. A.	1998	Increasing communicative interactions of young children with autism using a voice output communication aid and naturalistic teaching.	*		*		*	
Durand, V. M.	1999	Functional communication training using assistive devices: Recruiting natural communities of reinforcement.	*					
Dyches, T. T., Davis, A., Lucido, B., & Young, J.	2002	Generalization of skills using pictographic and voice output communication devices.	*		*	*		
Sigafoos, J., O'Reilly, M., Seely-York, S., & Edrisinha, C.	2004	Teaching students with developmental disabilities to locate their AAC device.	*	*				
Sigafoos, J., O'Reilly, M., Ganz, J. B., Lancioni, G. E., & Schlosser, R. W.	2005	Supporting self-determination in AAC interventions by assessing preference for communication devices.	*	*				
Bock, S. J., Stoner, J. B., Beck, A. R., Hanley, L., & Prochnow, J.	2005	Increasing functional communication in non-speaking preschool children: Comparison of PECS and VOCA.	*	*	*			
Son, S.-H., Sigafoos, J., O'Reilly, M., & Lancioni, G. E.	2006	Comparing two types of augmentative and alternative communication systems for children with autism.	*		*			
Olive, M. L., de la Cruz, B., Davis, T. N., Chan, J. M., Lang, R. B., O'Reilly, M. F., & Dickson, S. M.	2007	The effects of enhanced milieu teaching and a voice output communication aid on the requesting of three children with autism.	*		*			
Schlosser, R. W., Sigafoos, J., Luiselli, J. K., Angermeier, K., Harasymowyz, U., Schooley, K., & Belfiore, P. J.	2007	Effects of synthetic speech output on requesting and natural speech production in children with autism: A preliminary study.	*		*		*	
Olive, M. L., Lang, R. B., & Davis, T. N.	2008	An analysis of the effects of functional communication and a voice output communication aid for a child with autism spectrum disorder.	*		*			
Cannella-Malone, H. I., DeBar, R. M., & Sigafoos, J.	2009	An examination of preference for augmentative and alternative communication devices with two boys with significant intellectual disabilities	*		*		*	
Trembath, D., Balandin, S., Togher, L., & Stancliffe, R. J.	2009	Peer-mediated teaching and augmentative and alternative communication for preschool-aged children with autism.	*		*			
Franco, J. H., Lang, R. L., O'Reilly, M. F., Chan, J. M., Sigafoos, J., & Rispoli, M.	2009	Functional analysis and treatment of inappropriate vocalizations using a speech-generating device for a child with autism.	*		*			
Sigafoos, J., Green, V. A., Payne, D., Son, S. H., O'Reilly, M., & Lancioni, G. E.	2009	A comparison of picture exchange and speech-generating devices: Acquisition, preference, and effects on social interaction	*		*		*	
Kagohara, D. M., van der Meer, L., Achmadi, D., Green, V. A., O'Reilly, M. F., Mulloy, A., ... Sigafoos, J.	2010	Behavioral intervention promotes successful use of an iPod-based communication device by an adolescent with autism.	*		*		*	
Choi, H., O'Reilly, M., Sigafoos, J., & Lancioni, G.	2010	Teaching requesting and rejecting sequences to four children with developmental disabilities using augmentative and alternative communication.	*		*		*	
Banda, D. R., Copple, K. S., Koul, R. K., Sancibrian, S. L., & Bogschutz, R. J.	2010	Video modeling interventions to teach spontaneous requesting using AAC devices to individuals with autism: a preliminary investigation.	*		*			
Trottier, N., Kamp, L., & Mirenda, P.	2011	Effects of peer-mediated instruction to teach use of speech-generating devices to students with autism in social game routines	*		*			
Flores, M., Musgrove, K., Renner, S., Hinton, V., Strozier, S., Franklin, S., & Hil, D.	2012	A comparison of communication using the Apple iPad and a picture-based system.	*		*	*		
Achmadi, D., Kagohara, D. M., van der Meer, L., O'Reilly, M. F., Lancioni, G. E., Sutherland, D., ... & Sigafoos, J.	2012	Teaching advanced operation of an iPod-based speech-generating device to two students with autism spectrum disorders	*	*	*		*	
van der Meer, L., Kagohara, D., Achmadi, D., O'Reilly, M. F., Lancioni, G. E., Sutherland, D., & Sigafoos, J.	2012b	Speech-generating devices versus manual signing for children with developmental disabilities.	*		*		*	
van der Meer, L., Sutherland, D., O'Reilly, M. F., Lancioni, G. E., & Sigafoos, J.	2012c	A further comparison of manual signing, picture exchange, and speech-generating devices as communication modes for children with autism spectrum disorders.	*		*		*	

Table 1 (continued)

Authors	Year	Title	PECS phase equivalents included					
			I	II	III	IV	V	VI
van der Meer, L., Didden, R., Sutherland, D., O'Reilly, M. F., Lancioni, G. E., & Sigafoos, J.	2012a	Comparing three augmentative and alternative communication modes for children with developmental disabilities.	*		*		*	
Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Green, V., Oliva, D., Buonocunto, F., ... Di Nuovo, S.	2012	Technology-based programs to support forms of leisure engagement and communication for persons with multiple disabilities: Two single-case studies.	*		*			
Kagohara, D. M., van der Meer, L., Achmadi, D., Green, V. A., O'Reilly, M. F., Lancioni, G. E., ... & Sigafoos, J.	2012	Teaching picture naming to two adolescents with autism spectrum disorders using systematic instruction and speech-generating devices						*
van der Meer, L., Kagohara, D., Achmadi, D., Green, V. A., Herrington, C., Sigafoos, J., et al.	2011	Teaching functional use of an iPod-based speech-generating device to individuals with developmental disabilities	*		*		*	
Lorah, E. R., Tincani, M., Dodge, J., Gilroy, S., Hickey, A., & Hantula, D.	2013	Evaluating picture exchange and the iPad™ as a speech-generating device to teach communication to young children with autism.	*		*		*	
Van der Meer, L., Kagohara, D., Roche, L., Sutherland, D., Balandin, S., Green, V. A., ... Sigafoos, J.	2013	Teaching multi-step requesting and social communication to two children with autism spectrum disorders with three AAC options.	*		*	*	*	
Dundon, M., McLaughlin, T. F., Neyman, J., & Clark, A.	2013	The effects of a model, lead, and test procedure to teach correct requesting using two apps on an iPad® with a 5-year-old student with autism spectrum disorder.	*		*		*	
Ward, M., McLaughlin, T. F., Neyman, J., & Clark, A.	2013	Use of an iPad application as functional communication for a five-year-old preschool student with autism spectrum disorder.	*		*		*	
Boesch, M. C., Wendt, O., Subramanian, A., & Hsu, N.	2013	Comparative efficacy of the Picture Exchange Communication System (PECS) versus a speech-generating device: Effects on requesting skills.	*	*	*			
Ganz, J. B., Hong, E. R., & Goodwyn, F. D.	2013	Effectiveness of the PECS Phase III app and choice between the app and traditional PECS among preschoolers with ASD.	*		*	*		
Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., Achmadi, D., Stevens, M., Roche, L., ... Marschik, P. B.	2013	Teaching two boys with autism spectrum disorders to request the continuation of toy play using an iPad®-based speech-generating device.	*				*	
Couper, L., van der Meer, L., Schäfer, M. C., McKenzie, E., McLay, L., O'Reilly, M. F., ... Sutherland, D.	2014	Comparing acquisition of and preference for manual signs, picture exchange, and speech-generating devices in nine children with autism spectrum disorder.	*				*	
Strasberger, S. K., & Ferreri, S. J.	2014	The effects of peer assisted communication application training on the communicative and social behaviors of children with autism.	*	*	*	*	*	*
Gevarter, C., O'Reilly, M. F., Rojeski, L., Sammarco, N., Sigafoos, J., Lancioni, G. E., & Lang, R.	2014	Comparing acquisition of AAC-based mands in three young children with autism spectrum disorder using iPad® applications with different display and design elements.	*					
Desai, T., Chow, K., Mumford, L., Hotze, F., & Chau, T.	2014	Implementing an iPad-based alternative communication device for a student with cerebral palsy and autism in the classroom via an access technology delivery protocol.	*		*			
Roche, L., Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., Schlosser, R. W., Stevens, M., ... Carnett, A.	2014	An evaluation of speech production in two boys with neurodevelopmental disorders who received communication intervention with a speech-generating device.	*		*		*	
Waddington, H., Sigafoos, J., Lancioni, G. E., O'Reilly, M. F., Van der Meer, L., Carnett, A., ... Sutherland, D.	2014	Three children with autism spectrum disorder learn to perform a three-step communication sequence using an iPad®-based speech-generating device.	*		*		*	
Achmadi, D., Sigafoos, J., van der Meer, L., Sutherland, D., Lancioni, G. E., O'Reilly, M. F., ... Marschik, P. B.	2014	Acquisition, preference, and follow-up data on the use of three AAC options by four boys with developmental disability/delay.	*				*	
Lorah, E. R., Parnell, A., & Speight, D. R.	2014	Acquisition of sentence frame discrimination using the iPad™ as a speech-generating device in young children with developmental disabilities.						*
King, M. L., Takeguchi, K., Barry, S. E., Rehfeldt, R. A., Boyer, V. E., & Mathews, T. L.	2014	Evaluation of the iPad in the acquisition of requesting skills for children with autism spectrum	*	*	*	*		
Kasari, C., Kaiser, A., Goods, K., Nietfeld, J., Mathy, P., Landa, R., ... Almirall, D.	2014	Communication interventions for minimally verbal children with autism: A sequential multiple assignment randomized trial.	*	*	*	*	*	*
Shih, C.-H., Chiang, M.-S., Wang, S.-H., & Chen, C.-N.	2014	Teaching two teenagers with autism spectrum disorders to request the continuation of video playback using a touchscreen computer with the function of automatic response to requests	*					

Table 1 (continued)

Authors	Year	Title	PECS phase equivalents included					
			I	II	III	IV	V	VI
Stasolla, F., De Pace, C., Damiani, R., Di Leone, A., Albano, V., & Perilli, V.	2014	Comparing PECS and VOCA to promote communication opportunities and to reduce stereotyped behaviors by three girls with Rett syndrome	*	*	*			
Copple, K., Koul, R., Banda, D., & Frye, E.	2015	An examination of the effectiveness of video modelling intervention using a speech-generating device in preschool children at risk for autism	*		*			
Nepo, K., Tincani, M., Axelrod, S., & Meszaros, L.	2015	iPod Touch® to Increase Functional Communication of Adults with Autism Spectrum Disorder and Significant Intellectual Disability.	*		*			
Lorah, E. R., Karnes, A., & Speight, D. R.	2015	The Acquisition of Intraverbal Responding using a Speech Generating Device in School Aged Children with Autism.						*
Still, K., May, R. J., Rehfeldt, R. A., Whelan, R., & Dymond, S.	2015	Facilitating derived requesting skills with a touchscreen tablet computer for children with autism spectrum disorder.	*		*			
McLay, L., van der Meer, L., Schäfer, M. C., Couper, L., McKenzie, E., O'Reilly, M. F., ... Sutherland, D.	2015	Comparing acquisition, generalization, maintenance, and preference across three AAC options in four children with autism spectrum disorder	*				*	
Gevarter, C., O'Reilly, M. F., Kuhn, M., Mills, K., Ferguson, R., Watkins, L., ... Lancioni, G. E.	2016	Increasing the vocalizations of individuals with autism during intervention with a speech-generating device. Journal of applied behavior analysis	*					
Lorah, E. R.	2016	Comparing Teacher and Student Use and Preference of Two Methods of Augmentative and Alternative Communication: Picture Exchange and a Speech-Generating Device.	*		*			
McLay, L., Schäfer, M. C., van der Meer, L., Couper, L., McKenzie, E., O'Reilly, M. F., ... & Sutherland, D.	2016	Acquisition, Preference and Follow-up Comparison Across Three AAC Modalities Taught to Two Children with Autism Spectrum Disorder.	*				*	
Simacek, J., Reichle, J., & McComas, J. J.	2016	Communication Intervention to Teach Requesting Through Aided AAC for Two Learners with Rett Syndrome.	*		*		*	
Tönsing, K. M.	2016	Supporting the production of graphic symbol combinations by children with limited speech: a comparison of two AAC systems.						*

Note: Included studies were assessed and the range of communication skills (e.g., PECS phases) were scored as being present or not present as denoted by an "*" or a blank space, respectively

3.98%), Children Disintegrative Disorder (n = 1; 0.44%), Down Syndrome (n = 5; 2.21%), Hearing Impairment (n = 1; 0.44%), Hydrocephaly (n = 1; 0.44%), Klinefelter Syndrome (n = 1; 0.44%), Mitochondrial Disorder (n = 1; 0.44%), Perisylvian Disorder (n = 1; 0.44%), Rett Syndrome (n = 5; 2.21%), Schizoaffective Disorder (n = 1; 0.44%), Seizure Disorder (n = 9; 3.98%), and Spina Bifida (n = 1; 0.44%) as well.

Discussion

Assessment of the Literature

Communication training using high-tech, touchscreen AAC devices continues to be an active area of research, with rates of publications increasing exponentially in recent years. This continued activity is enhanced by a growing range of capable touchscreen devices, a variety of suitable mobile applications, and lower overall costs in acquiring and maintaining suitable touchscreen devices and software. As indicated in this review of the current literature, high-tech AAC approaches continue to be pursued as a replacement for more traditional, low-tech approaches (i.e., PECS, picture exchange) in the treatment of deficient or absent social and communication skills (e.g., requests, answering questions). This trend is understandable, as mobile devices preclude the need to prepare and replenish materials, have high re-usability, and assist with organization—all of which are conducive to resource-strained settings, such as schools. However, many aspects of these newer alternatives have yet to be fully explored. At present, the available literature provides little guidance regarding how the generated vocal response is to fully replace the social act of approaching an individual and exchanging some form of communication (e.g., picture card, sentence strip). Further, relatively little has been done regarding how to teach individuals with disabilities to overcome the new issues and barriers that inevitably arise when operating these devices (e.g., low battery, volume muted, application minimized, multiple applications available on device). While educators and other stakeholders should continue to capitalize on new technologies and the benefit they afford, there are several areas that warrant additional consideration if high-tech AAC methods are to fully replace the well-established low-tech approaches (e.g., PECS).

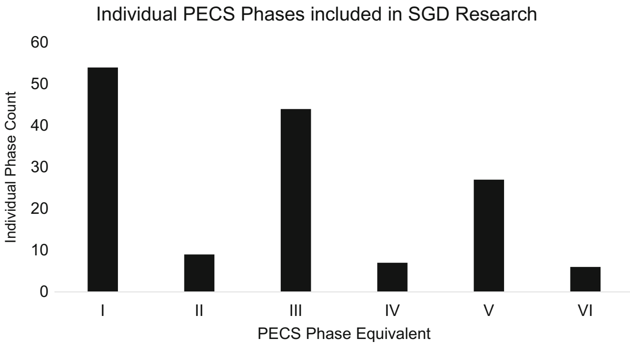

Fig. 2 PECS phases evaluated in speech-generating device research

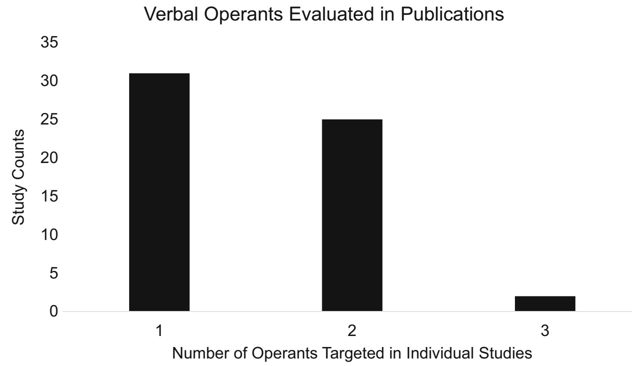

Fig. 4 Range of verbal operants included in SGD treatment studies

With respect to the first research question, have high-tech alternatives to low-tech AAC been evaluated within all core components of the PECS training program, the results of this review indicated that components of the PECS protocol have indeed been translated into a range of procedures utilizing high-tech AAC, though this has been conducted varying degrees and with widely varying progressions. As alluded to in earlier reviews on this topic, procedures analogous to Phases I, III, IV, and V of the PECS protocol (e.g., the mand and intraverbal-mand; requesting and answering questions related to requests) have been frequently demonstrated using high-tech AAC devices and software. These approaches have been largely mirrored traditional card exchange procedures, substituting the "Pick up, Reach, and Release" response with some manner of pressing a touchscreen. However, the findings from this review highlight substantial variability within the training sequences put forward to establish this newer requesting response, and responding to questions related to requests, using high-tech AAC.

Within the more advanced requesting skills (i.e., Phase IV), answering questions related to requests, a significant portion of studies targeted this skill (i.e., intraverbal-mand) absent any form of icon discrimination and the overwhelming majority of these studies did not include sentence structure as a prerequisite skill within the teaching sequence (e.g., "What do you want?", "Juice"). For the mand and intraverbal-mand skills overall (i.e., Phases I, III–V), more than half of the included studies included a single, typically varying, component of

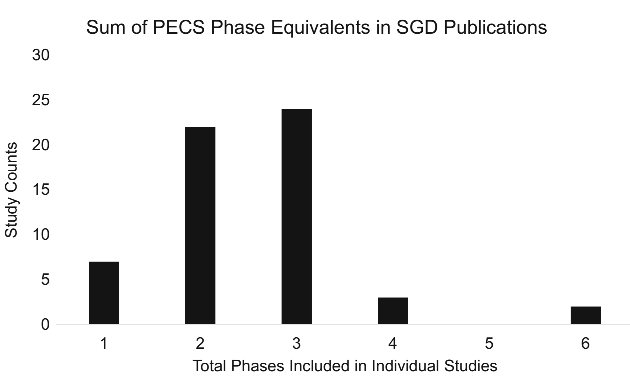

Fig. 3 Extent of PECS phases included in individual studies

icon discrimination but only a very small percentage of these studies include checks for correspondence between communication and preference. These observations draw attention to significant variations in the teaching and training sequences put forward in the literature, with many of the practices for establishing "requesting behavior" loosely referring to the acquisition of either the mand or the intraverbal-mand, in some varying order or combination.

In the few studies that examined social and communication training beyond requesting behavior (e.g., answering social questions, making comments; Phase VI), the majority of teaching sequences put forward to establish the intraverbal-tact (e.g., answering general questions, commenting) investigated this type of verbal behavior in isolation. In these studies, teaching focused on training the learner to respond to some query (e.g., "what do you see", "what do you hear?") using the communication device. As such, these teaching procedures were not evaluated as part of a teaching sequence that progressed from other earlier, but relevant, operants towards more complex and social forms of communication. This is a substantial gap in the high-tech literature, since there are very few studies that link initial communication training to these more advanced and social forms of communication, such as provided in PECS. As recently noted in Lorah et al. (2015a), these more advanced forms of communication (i.e., the intraverbal and intraverbal-tact) are often considered to be a core component of most interventions designed to address deficits in socialization and other related social skills (e.g., social questions), a hallmark target for intervention when working with individuals with ASD or related disabilities (Bondy et al. 2004; Lorah et al. 2015a).

Lastly, procedures analogous to Phase II of the PECS protocol (e.g., traveling, persistence in communication) were largely absent in the studies reviewed. Fewer than ten studies incorporated problem-solving and travel as a necessary component of communication. The PECS protocol emphasizes the importance of this teaching early in, as well as throughout, communication training to prepare the learner to demonstrate

Table 2 Clinical populations within reviewed studies

Population	Participants in sample	Total participants	Percent of sample (%)
Angelman Syndrome	1	226	0.44
Autism Spectrum Disorder	190	226	84.07
Cerebral Palsy	9	226	3.98
Child Disintegrative Disorder	1	226	0.44
Down Syndrome	5	226	2.21
Hearing Loss	1	226	0.44
Hydrocephaly	1	226	0.44
Intellectual Disability	59	226	26.11
Klinefelter Syndrome	1	226	0.44
Mitochondrial Disorder	1	226	0.44
Perisylvian Disorder	1	226	0.44
Rett Syndrome	5	226	2.21
Schizoaffective Disorder	1	226	0.44
Seizure Disorder	9	226	3.98
Spina Bifida	1	226	0.44

independent and spontaneous communicative behavior when barriers, such as distance or changes in context, are inevitably encountered (Bondy and Frost 1994). In the case of high-tech AAC, Phase II programming could plausibly take the form of preparing the learner to seek and/or activate a device or having to relocate to a location where a listener of interest could hear the emitted spoken response. Phase II procedures are doubly important as a means to prevent the learner from mistakenly associating social or communicative behavior with any singular, isolated, or restricted context (e.g., only in the classroom, with a single instructor; Bondy and Frost 1994).

As per the second research question, to what degree has the existing literature on high-tech AAC investigated procedures for teaching the mand, the intraverbal-mand, and the intraverbal-tact using high-tech AAC, the results from this review suggest that the present literature has focused overwhelmingly on the acquisition of a "requesting behavior." However, absent a clear and easily replicable teaching sequence, many researchers have taken various routes to establish "requesting behavior." Over 90% of the included studies targeted requesting, with roughly half targeted the mand and the other targeted the intraverbal-mand. This divide is misleading, however, as the majority of studies have investigated these operants not as a sequential progression, but as separate and seemingly interchangeable routes to establishing "requesting behavior" at the outset of intervention. Beyond requesting, the number of studies examining the intraverbal-tact, and other more social forms of communication, has lagged significantly behind. The results of this review indicated that roughly 10% of included studies targeted skills beyond that of requests. Furthermore, of the few studies included in this review that included these targets, the range of skills taught were limited and established apart from the other verbal operants (i.e., not part of any teaching sequence).

Future Considerations for Researchers

Research on the use of high-tech mobile devices as AAC tools to establish a range of verbal behavior continues to expand rapidly, year after year. A range of teaching procedures have been proposed to replace low-tech approaches to communication training with high-tech complements and support for these procedures continues to grow. While this line of research is likely to address many of the observations in this review at some point in the future, present and future researchers could more readily take steps address the limitations of the current research base in the following ways. First, the development of a unified training sequence similar to, or inspired by, the PECS protocol would substantially increase the ease and likelihood of systematic replication by others. Without an agreed-upon teaching sequence, and list of component skills to base intervention packages upon, systematic replications and widespread dissemination of high-tech AAC methods could be challenging for both applied clinicians and researchers alike. For researchers, the absence of a shared set of guidelines has led to heterogeneous collection of teaching procedures in the research, and for applied clinicians, the varying methods and procedures available has not coalesced and presented users with a clear and coherent set of training procedures for beginning communicators to more advanced and social learners. An established teaching sequence and guidelines for its use might also serve to broaden the scope of communication training and more clearly link initial communication training (e.g., requesting) to more social outcomes in the future. Second, the present literature on high-tech AAC would benefit from incorporating components of low-tech tech approaches (i.e., PECS), rather than replacing them outright. The manualized procedures put forth in PECS, if incorporated into high-tech approaches, could potentially enhance the consistency of discrimination training (i.e., nonpreferred-preferred procedures prior to preferred-preferred, correspondence checking guidelines), the spontaneity and independence of communication (e.g., traveling, problem-solving), and error correction. Incorporating established procedures present in historical approaches may also benefit clinicians and educators who desire to adopt high-tech AAC that have prior training and familiarity with the PECS protocol.

Limitations

While this review utilized a methodical approach to categorizing social and communicative skills in published works, several potential sources of bias exists. First, this review included only works published in peer-reviewed journals. Additional teaching procedures used in high-tech AAC may have been evaluated in clinical works but not published in academic journals. Similarly, many researchers may be actively researching the areas of need highlighted in this review at the present time. Additionally, the individual studies included in the search may have been biased by the level of technology available at the time of publication (e.g., multi-touch functionality, battery life, data storage, wireless internet). Given that the included studies span over two decades, the functionality afforded by technology was likely constrained by the technological capabilities of available devices at the time.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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