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A Meta-Analysis of Single Case Research Studies on Aided Augmentative and Alternative Communication Systems with Individuals with Autism Spectrum Disorders

Jennifer B. Ganz · Theresa L. Earles-Vollrath · Amy K. Heath · Richard I. Parker · Mandy J. Rispoli · Jaime B. Duran

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Abstract Many individuals with autism cannot speak or cannot speak intelligibly. A variety of aided augmentative and alternative communication (AAC) approaches have been investigated. Most of the research on these approaches has been single-case research, with small numbers of participants. The purpose of this investigation was to meta-analyze the single case research on the use of aided AAC with individuals with autism spectrum disorders (ASD). Twenty-four single-case studies were analyzed via an effect size measure, the Improvement Rate Difference (IRD). Three research questions were investigated concerning the overall impact of AAC interventions on targeted behavioral outcomes, effects of AAC interventions on individual targeted behavioral outcomes, and effects of three types of AAC interventions. Results indicated that, overall, aided AAC interventions had large effects on targeted behavioral outcomes in individuals with ASD. AAC interventions had positive effects on all of the targeted behavioral outcome; however, effects were greater for communication skills than other categories of skills. Effects of the Picture Exchange Communication System and speech-generating devices were larger than those for other picture-based systems, though picture-based systems did have small effects.

Keywords Autism spectrum disorders · Augmentative and alternative communication · Aided AAC · Communication skills · Social skills · Interventions · Meta-analysis · Voice output communication aid · Speech-generating device · Picture Exchange Communication System

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J. B. Ganz · A. K. Heath · R. I. Parker · M. J. Rispoli · J. B. Duran
Texas A&M University, College Station, TX, USA
e-mail: akheath@neo.tamu.edu

R. I. Parker
e-mail: Rip_parker@msn.com

M. J. Rispoli
e-mail: mrispoli@tamu.edu

J. B. Duran
e-mail: Jduran23@neo.tamu.edu

T. L. Earles-Vollrath
University of Central Missouri, Warrensburg, MO, USA
e-mail: vollrath@ucmo.edu

J. B. Ganz (✉)
Department of Educational Psychology, 4225 TAMU, College Station, TX, USA
e-mail: jeniganz@tamu.edu

Individuals who cannot effectively use conventional speech to communicate may use augmentative and alternative communication (AAC) systems to compensate for a lack of speech or to replace, or augment, unintelligible speech. Difficulty or delay in language development is a core characteristic associated with autism spectrum disorders (ASD; American Psychiatric Association [APA] 2000); approximately half of children with autism do not develop speech or develop limited speech and language abilities (Centers for Disease Control and Prevention [CDC] 2007). Given this statistic, many professionals implement AAC with individuals with ASD (Mirenda 2003).

Examples of AAC include unaided systems, such as gestures and manual sign language, and aided systems, such as pointing to a picture on a communication board, writing on paper, activating a speech-generating device (SGD; American Speech-Language-Hearing Association [ASHA] 1997), or exchanging a symbol, as when using a Picture Exchange Communication System (PECS) (Frost and Bondy 1994, 2002). Many practitioners choose aided AAC systems for individuals with ASD that require external equipment (Bondy and Frost 2002; Mirenda 2001). Aided, picture-based AAC systems are frequently implemented with individuals with ASD; such systems appear to match the characteristics of ASD (Mirenda 2001; Schuler and Baldwin 1981). Fine motor difficulties are common in individuals with ASD, thus causing difficulty in learning manual signs (Jones and Prior 1985; Mirenda 2001; Seal and Bonvillian 1997). However, picture-based systems are concrete, remain present to refer back to (unlike manual signs, which are transient), and many resemble their referents and appear to be well suited for individuals with ASD (Mirenda 2001; Rotholz et al. 1989). Thus, aided systems are the focus of this article. Speech generating-devices (SGDs), also known as voice output communication aids (VOCAs), are portable electronic aided AAC devices that usually combine digitized or synthesized speech with static visual symbols such as line drawings, photographs, or abstract symbols (Mirenda 2003; Ogletree and Oren 2006).

While numerous AAC systems exist, some of the systems most widely used with children with autism include SGDs (e.g., Schlosser et al. 1998; Sigafoos et al. 2004), PECS (Bondy and Frost 2002; Frost and Bondy 2002), and other picture-based systems (e.g., Frea et al. 2001; Nunes and Hanline 2007), thus, they are the focus of this article. Although manual sign language is considered to be an emerging treatment for individuals with ASD, a recent systematic review of the literature (Wendt 2009) included a focus on sign language implementation with this population, thus, sign language was excluded from the current analysis.

History of AAC in ASD

There has been a strong movement in the field to identify evidence-based practices (EBP) for individuals with autism (Reichow et al. 2008; Schlosser and Sigafoos 2009; Simpson 2005, 2008; Simpson et al. 2007). This movement was initiated with the legal mandates of NCLB (2001) and the IDEA (2004) requiring school personnel to implement "…special education and related services and supplementary aids and services, based on peer-reviewed research to the extent practicable…" (IDEA 2004, 20 U.S.C. 1414 §614, p. 118). Additional support for this movement was provided by researchers such as Horner et al. (2005), who proposed standards for using single-subject design research to identify EBP in special education.

Research is the foundation for determining EBP in special education (Tankersley et al. 2008), however, due to the low incidence of some disabilities, researchers often use single-case designs rather than more conventional group designs. Issues arise when professionals attempt to synthesize and aggregate the data from numerous single-subject design studies to determine EBP. A primary difficulty relates to the amount of research being conducted. Special education has an extremely large single-case research base which makes it difficult to evaluate and summarize the results unless organized into a useable form (Kavale 2001). In addition, comparing results of research using different single-subject designs, diverse outcome measures and participants with varying demographics, as well as the variable and sometimes conflicting results of the research (Kavale 1984, 2001) makes it difficult to summarize the findings without a common metric. Further, although some group studies on AAC for individuals with ASD do exist, they are few in number compared to the plethora of single-case studies and they have been excluded from this meta-analysis because it is not possible to use a single index to compare these two different methods of research.

Meta-analysis combines and synthesizes results of numerous single-participant studies from an area of research allowing professionals to determine the general effectiveness of the selected interventions and with whom these practices produce the greatest benefits (Kavale 1984, 1998, 2001). In addition, meta-analysis addresses many of the previously stated concerns (Kavale 1984, 2001) while providing a quantitative means for synthesizing research (Glass 1976; Kavale 2001) making it an effective metric for identifying EBP in special education (Banda and Therrien 2008). Meta-analysis commonly converts data from each of the studies into an effect size (ES) which indicates the amount of change between baseline and intervention phases (Kavale 1998). The ES is comparable to the normal distribution and z-score, therefore confidence intervals can be derived. Effect sizes can be positive or negative, however, the closer the ES is to 1.0, the larger the effect of the intervention on the outcome variables.

While numerous researchers promote the use of meta-analysis in summarizing single-case research (Banda and Therrien 2008; Kavale 1984, 1998, 2001; Marquis et al. 2000; Parker et al. 2007; Scruggs 1992; Scruggs and Mastropieri 1998; Scruggs et al. 1987) controversy exists regarding the type of metric to use (Scruggs, 1992; Scruggs and Mastropieri 2001). Percent of non-overlapping data points (PND; Scruggs et al. 1987) is the most commonly used index; however, concerns regarding the use of PND as a single-case research statistical indices have been documented (Allison and Gorman 1993; Scruggs and Mastropieri 2001; Parker et al. 2007) including the need for a clear description of the guidelines used when applying the procedure (Scruggs et al. 1987; Parker et al. 2007), inability to calculate confidence intervals because of an unknown sampling distribution (Parker et al. 2007) the overestimation of treatment effects when the baseline trend is in the expected direction of the treatment data (Scruggs et al. 1987), decreased reliability due to an emphasis on the most extreme data point in phase A (Parker et al. 2007) and the lack of sensitivity to powerful treatment effects (White et al. 1989). Another index is the percent of all non-overlapping data points (PAND, Parker et al. 2007). PAND is similar to PND in that it focuses on non-overlapping data points, however, it uses all data points from each of the phases thus addressing the criticism that PND relies on the most extreme, therefore unreliable, data point (Parker et al. 2007). In addition, PAND can be converted into an effect size and has a sampling distribution which allows for the calculation of confidence intervals (Parker et al. 2007). PAND, however, like PND, is insensitive to ES at the top of the scale and does not account for positive changes in baseline trend (Parker et al. 2007).

The abovementioned shortcomings have spurred the development of more defensible non-overlap indices, one of which is the Improvement Rate Difference (IRD). IRD is defined as the improvement rate (IR) of the treatment phase minus the improvement rate of the baseline phase [IR (t) − IR (b) = IRD]. The IR is calculated by number of "improved data points" divided by the total data points in that phase. IRD is calculated as the difference between the two independent proportions. This meta-analysis relies on IRD, with confidence intervals (CIs) to indicate precision and credibility of obtained IRD values. However, PND analyses are included also, for readers who are familiar with that earlier index.

Purpose and Research Questions

The purpose of this meta-analysis was to investigate the effectiveness of various augmentative and alternative communication (AAC) systems and procedures that are currently implemented with individuals with autism spectrum disorders (ASD). As noted above, the pressure to implement EBP in schools calls for the need to determine the overall effectiveness of AAC (Tankersley et al. 2008). Thus, although several single-case studies have demonstrated the efficacy of AAC with individuals with ASD, it is critical to evaluate that data using a common metric, i.e., an effect size measure via a meta-analysis (Kavale 1984, 1998, 2001). The first research question seeks to solve this problem: (a) What are the overall effects of AAC on the behaviors (e.g., communication skills, social skills, challenging behaviors, and academic skills) of children with ASD?

Beyond determining the overall impact of AAC, it is also necessary to determine the effects of AAC on individual types of targeted behavioral outcomes. While single-case research has demonstrated that AAC may be effective in improving communication skills (e.g., Charlop-Christy et al. 2002), social skills (e.g., Kravits et al. 2002), challenging behaviors (e.g., Frea et al. 2001; Ganz et al. 2009), and academics (e.g., Schlosser et al. 1998), it is unclear whether AAC is more effective for one type of behavior than others. Thus, the second research question asks: (b) Do effects differ by targeted client outcome (dependent variable)?

Finally, although a number of single-case studies have demonstrated the effectiveness of PECS (e.g., Ganz and Simpson 2004), SGDs (e.g., Schepis et al. 1998), and other picture-based AAC systems (e.g., Thompson et al. 1998), few studies have compared the effectiveness of these systems to each other. Meta-analysis allows for such comparisons to be made (Banda and Therrien 2008). This provides a means to answer the final research question: (c) Do effects differ by type of AAC treatment variables (e.g., Picture Exchange Communication System, other picture-based system, or use of speech-generating devices)?

Method

Literature Search

A literature search was conducted that focused on the use of AAC systems with individuals with ASD. *ERIC*, *PsychINFO*, *Education Full Text*, *Professional Development Collection*, and *Social Sciences Full Text* online databases were searched for literature published between 1980 and the first 6 months of 2008 that contained one of the following keywords: *autis**, *autism spectrum disorder**, *ASD*, *pervasive developmental disorder**, *PDD*, *PDD-NOS*, *Asperger**, *Asperger syndrome*, and *Asperger's syndrome* and one of these keywords: *AAC*, *augmentative communication*, *alternative communication*, *augmentative and alternative communication*, *PECS*, and *Picture Exchange Communication System*. This search resulted in 122 articles, books, book chapters, dissertations, and other literature.

Procedures

Following the literature search, each article or document was evaluated according to whether or not it met all of the following criteria: (a) participants were diagnosed with an ASD (i.e., any of the PDD diagnoses in the DSM-IV-TR;

American Psychiatric Association 2000); (b) outcome measures included one or more of these: social skills, adaptive behavior, challenging behavior, communication, and academic skills; (c) interventions included aided AAC system (e.g., PECS, SGDs, voice output communication aids, picture-point systems); (d) study employed a single-case research design demonstrating experimental control (i.e., reversal, multiple-baseline, alternating treatment); (e) no dichotomous dependent variables (e.g., yes/no, 0/1) used; (f) data were displayed as line graphs; (g) articles were published in peer-reviewed journals; and (h) articles were in English. Articles had to meet all of these criteria to be included in the meta-analysis. Although a few group studies have been published demonstrating the effects of AAC on individuals with ASD (e.g., Yoder and Stone 2006a, b), these were excluded from this meta-analysis because it is not possible to meaningfully compare disparate types of data with a single effect size measure. Effect sizes from single case research are commonly two to three times larger than from group studies; thus they cannot be summarized statistically together (Beretvas and Chung 2008).

Each document was independently evaluated by two of the authors to determine if it met each of the inclusion criteria. The majority of the documents that were eliminated were dissertations (i.e., not peer-reviewed publications), were descriptive articles (e.g., described how to implement PECS, were large group studies, or did not include participants with ASD. A small number of excluded documents were in Japanese or included single-case designs that did not demonstrate experimental control (e.g., Ganz et al. 2008a). In cases where inclusion judgments were in disagreement or one of the authors was unsure, a third author critiqued the article and the inclusion/exclusion decision made by two of the three authors stood. As a result, 24 articles were identified to include in the meta-analysis.

One of the authors then did a manual search of the articles referenced in the included articles. This search resulted in the inclusion of one additional article that met the aforementioned criteria. One article was later eliminated because the research design did not include the collection of baseline data with which to compare intervention results (Beck et al. 2008); thus, this meta-analysis includes the analysis of 24 single-case studies.

Data Extraction

Each of the 24 articles were summarized, including study design, brief participant descriptions (number, sex, age range, diagnosis), settings, intervention implemented, teaching method implemented, target behavioral outcomes, summary of the results, and overall quality of the research. The categories for intervention implemented were determined post hoc, that is, following the gathering of articles and according to the easiest means of categorizing the types of AAC, based on categories commonly used by practitioners. SGDs included any electronic AAC system that included synthetic or natural (recorded) speech output. PECS included only those articles that specifically identified the intervention as following the PECS protocol (Frost and Bondy 2002). Finally, PIC included any other picture-based AAC system; that is, any AAC system that did not include electronic voice output and did not follow the PECS protocol of instruction and implementation.

The teaching method implemented included three categories. Child-led involved instruction that began only when the child initiated an interaction by displaying a behavioral indication that he or she wished to obtain the item (e.g., reached for, tried to grab, intently stared at the item) and instruction consisted of massed trials, often stimuli or controlled by the adult. Naturalistic generally fit the criteria for child-led, however, instruction took place during natural activities (e.g., free play, snack time); the adult did not strictly control access to the stimuli. Teacher-led involved one-on-one instruction in a contrived situation in which instruction was given with no clear behavioral indication that the child wished to obtain the item. Instruction was also considered teacher-led if the teacher led the communication situation with a prompt such as, “what do you want,” or, “time to make choices.”

Horner et al. (2005) suggestions for determining the quality of research were considered. As a result, the overall quality of research column in Table 1 includes the number of phase change comparisons as well as the range of calculated IRD results for each article. According to Horner et al. (2005), a minimum of three phase changes demonstrating experimental control is required in studies considered to be high quality. Horner et al. (2005) describe seven quality indicators to determine whether or not individual single-case studies should be considered to be credible: (a) participant and setting descriptions; (b) independent variables; (c) dependent variables; (d) baseline measurement; (e) experimental control, or internal validity; (f) external validity; and (g) social validity.

Overall, the studies included in this meta analysis meet most of the Horner et al. criteria, particularly replicable descriptions of participants and settings, replicable description of and systematic manipulation of the independent variable(s), measurement and description of the dependent variable(s), collection of and high overall interobserver agreement, replicable description of baseline conditions and collection of baseline data (although some of the studies included only two to three baseline data points for some participants; e.g., Ganz et al. 2008b), and single-case designs demonstrating experimental control.

Table 1 Summaries of articles included in the analysis

Authors	Single-case design	Participant(s)	Setting	Intervention & teaching method	Target behavioral outcome(s)	Summary of results	Quality of research
Angermeier et al. (2008)	Alternating treatment combined with multiple baseline across participants	Four boys; ages 6–9 years; AUT, PDD	School (private assessment suite)	PECS; child-led	Percentage of correct picture requests	All participants achieved mastery for phase I & II with similar results for both PCS and Bliss symbols. Phase III was less consistent	3 phase change Comparisons IRD Range of (.00–.89)
Buckley and Newchok (2005)	Reversal	One boy; age 7 years; AUT	School (private assessment suite)	PIC; teacher-led	Percentage of intervals with aggression and picture exchanges	FCT plus extinction was effective in decreasing aggressive behavior. Low effort conditions were more effective than high effort conditions	3 phase change comparisons IRD range: (.91–.99)
Charlop-Christy et al. (2002)	Multiple baseline across participants	Three boys; ages 3–12 years; AUT	Therapy rooms; classrooms; home	PECS; child-led, naturalistic, teacher-led	Frequency and percentage of intervals of social-communication skills and challenging behaviors	All participants mastered all PECS phases. Social communication increased while challenging behaviors decreased	32 phase change comparisons IRD range: (.00–.99)
Drager et al. (2006)	Multiple baseline across sets of symbols	One boy and one girl; age 4 years; AUT	Day care center; therapy rooms	PIC; teacher-led, naturalistic	Frequency of correct symbol comprehension and symbol production	Aided language modeling had a positive impact on all measured skills	12 phase change comparisons IRD range: (.40–.99)
Frea et al. (2001)	Multiple baseline across settings	One boy; age 4 years; AUT	Classroom (general education preschool)	PIC; child-led, naturalistic	Frequency of disruptive behaviors and picture exchanges	Disruptive behaviors decreased and communication skills increased	4 phase change comparisons IRD range: (.75–.99)
Ganz and Simpson (2004)	Changing criterion	Two boys and one girl; ages 3–7 years; AUT, DD	Classrooms (general education)	PECS; child-led	Percentage of independent picture requests, average words per trial, and percentage of trials with non-word vocalizations	All participants made progress toward mastery of PECS exchanges and verbal utterances. Skills generalized to other adults	3 Phase change comparisons IRD range: (.09–.47)
Ganz et al. (2008b)	Multiple baseline across participants	Two boys and one girl; ages 3–5 years; AUT, DD	Homes	PECS; child-led	Percentage of independent picture exchanges and word approximations, average number of intelligible words per trial	Two out of the three participants reached mastery. The final participant showed little progress	6 Phase change comparisons IRD range: (.84–.98)
Johnston et al. (2003)	Multiple probe across participants	Three boys; ages 4–5 years; AUT, DD, PDD	Classroom (special education preschool)	PIC; naturalistic	Percentage of correct use of communication skills	Participants were able to request entrance into play using pictures	3 Phase change comparisons IRD range: (.42–.50)

Table 1 continued

Authors	Single-case design	Participant(s)	Setting	Intervention & teaching method	Target behavioral outcome(s)	Summary of results	Quality of research
Kravits et al. (2002)	Multiple baseline across settings	One girl; age 6 years; AUT	Home; classroom (general education)	PECS; child-led	Frequency of spontaneous language and social interaction	Spontaneous verbalization increased across PECS settings. Verbalizations increased in two of three areas and social interaction increased in one setting	3 Phase change comparisons IRD range: (.82–.92)
Lund and Troha (2008)	Multiple baseline across participants	Two boys and one girl; ages 12–17 years; AUT, DD, VI	Classroom (self-contained)	PECS; child-led	Percentage of correct requests	One of three participants completed all phases. The other two participants showed improvement but did not reach mastery	3 Phase change comparisons IRD range: (.50–.61)
Marckel et al. (2006)	Multiple baseline across descriptors	Two boys; ages 4 and 5 years; AUT	Home	PECS; child-led	Frequency of independent requests with adjective improvisation	Number of improvised requests improved. Skills generalized across items, settings and people	6 Phase change comparisons IRD range: (.67–1.0)
Nunes and Hanline (2007)	Multiple baseline across routines	One boy; age 6 years; AUT	Home	PIC; naturalistic	Frequency of communication turns, imitative responses, use of AAC, and verbalizations or vocalizations	Rate of AAC use and verbal initiated responses increased. No increase was shown for imitative responses	10 Phase change comparisons IRD range: (.00–1.0)
Olive et al. (2007)	Multiple probe	Three boys; ages 3–5 years; AUT, PDD	Classroom (general education preschool)	SGD; naturalistic	Frequency of correct SGD request, incorrect SGD request, prompted SGD use, gesture or sign use, and verbalization or vocalization	All participants displayed an increase in total requesting and use of SGD	7 phase change comparisons IRD range: (.51–1.0)
Olive et al. (2008)	Multiple baseline	One girl; age 4 years; AUT	Home	SGD; Naturalistic	Frequency of challenging behavior, requesting attention, correct pronoun use, and incorrect pronoun use	Challenging behaviors decreased and use of VOCA increased	8 Phase change comparisons IRD range: (.29–1.0)
Reichle et al. (2005)	Multiple probe	One man; age 40 years; AUT, DD	Home	PIC; teacher-led	Percentage of picture requests	Requests for help and task completion increased	3 phase change comparisons IRD range: (.00–.20)
Schepis et al. (1998)	Multiple probe across participants and time	Three boys and one girl; ages 3–5 years; AUT	Classroom (self-contained)	SGD; naturalistic	Number of communicative interactions per minute	All participants displayed an increase in communicative interactions using VOCA	6 phase change comparisons IRD range: all = 1.0

Table 1 continued

Authors	Single-case design	Participant(s)	Setting	Intervention & teaching method	Target behavioral outcome(s)	Summary of results	Quality of research
Schlosser et al. (1998)	Adapted alternating treatment	One boy; age 10 years; AUT	School library; classroom (self-contained)	SGD; teacher-led	Percentage of words spelled correctly and correct letter sequences	Speech output alone and in combination with feedback lead to the highest increase in correct spelling and letter sequences	22 Phase change comparisons IRD range: (.00–1.0)
Schlosser et al. (2007)	Alternating treatment	Five boys; ages 8–10 years; AUT, DD	Classroom (self-contained)	SGD; teacher-led	Percentage of correct requests and correct elicited vocalizations	All participants showed improvement in correct requests in one or the other condition. Only one student improved in elicited vocalizations	6 Phase change comparisons IRD range: (.80–.89)
Schlosser and Blischak (2004)	Adapted alternating treatment	Four boys; ages 8–12 years; AUT	Classroom (self-contained)	SGD; teacher-led	Percentage of words spelled correctly and correct letter sequences	All four participants reached criterion in one or the other intervention method	24 Phase change comparisons IRD range: (.00–1.0)
Sigafoos et al. (2004)	Multiple baseline across participants	One boy and one woman; ages 16 and 20; AUT, DD, PDD, HI	Vocational training program office; classroom (self-contained)	SGD; naturalistic	Percentage of correct SGD use	SGD use increased and generalized to other skills	8 Phase change comparisons IRD range: (.14–1.0)
Sigafoos et al. (2004)	Delayed multiple baseline across participants	Two boys and one girl; ages 12–20 years; AUT, PDD	Vocational training program office; classroom (self-contained)	SGD; teacher-led	Percentage of correct SGD use	All participants learned to use the SGD and locate the device when not immediately available	3 Phase change comparisons IRD range: all = 1.0
Thompson et al. (1998)	Reversal	One boy; age 7 years; DD, PDD	Classroom in hospital	PIC; teacher-led	Rate and percentage of intervals of challenging behavior	Challenging behaviors were reduced as communication skills increased	2 phase change comparisons IRD range: (.00 & .64)
Tincani (2004)	Alternating treatment	One boy and one girl; ages 5 and 6 years; AUT, DD, PDD	Classroom (self-contained)	PECS; child-led	Percentage of picture requests and vocalizations	One participant responded more strongly to PECS while the other responded more positively to sign language. Vocalization increased for both participants	8 Phase change comparisons IRD range: (.73–1.0)

Table 1 continued

Authors	Single-case design	Participant(s)	Setting	Intervention & teaching method	Target behavioral outcome(s)	Summary of results	Quality of research
Tincani et al. (2006) (two studies within one article	Multiple baseline across participants	Two boys; ages 10 and 11 years; AUT	Separate room; classroom (self-contained)	PECS; child-led	Percentage of independent picture requests and vocalizations	Both participants mastered phases I-IV of PECS. One participant displayed vocalizations during phase IV	4 Phase change comparisons IRD range: (.00–1.0)
	Alternating treatment	One boy; age 9 years; AUT	Separate room; classroom (self-contained)	PECS; Child-led	Percentage of vocalizations	Vocalizations reached mastery only in the contingent reinforcement phase	

Diagnostic codes: AUT = autism/autistic disorder only (or only co-morbid with speech-language impairment), DD = developmental delay, developmental disability, mental retardation, cognitive/intellectual impairment, HI = hearing impairment, PDDNOS = pervasive developmental disorder-not otherwise specified, VI = visual impairment. Intervention codes: PECS = Picture Exchange Communication System, PIC = picture-based communication system/technique other than PECS, SGD = speech-generating device, voice output communication aid

However, as illustrated by Table 1, some studies that were included did not individually meet the criteria for experimental control (e.g., reversal designs with a single participant and no replication across participants, settings, or materials; e.g., Buckley and Newchok 2005). Although the dependent variables measured were all socially valid and important skills, many of the included studies did not measure social validity (e.g., Lund and Troha 2008; Schlosser et al. 1998). Seven of the included studies did include measures of social validity (Buckley and Newchok 2005; Johnston et al. 2003; Kravits et al. 2002; Marckel et al. 2006; Olive et al. 2008; Schlosser and Blischak 2004; Tincani 2004).

Measurement of Effect Sizes

Line graphs pertaining to the dependent variables were analyzed to determine a "magnitude of change index," or "effect size," called the Improvement Rate Difference (IRD; Parker et al. 2009). IRD has several advantages over other effect size indices including the use of simple calculations, the ability to supplement the visual analysis of graphed data, easily obtained confidence intervals, few distribution assumptions and application to complex single-subject designs and multiple data points (Parker et al. 2009). The application of IRD to single case research is quite new (Schneider et al. 2008); however, IRD is modeled after the "risk difference" from medical research (Armitage et al. 2002; Altman 1999; Sackett et al. 1997), which is promoted as a summary of treatment efficacy (http://www.cochrane.org/) by the prestigious Cochrane Collaboration (2006) for evidence-based medicine. IRD has been applied in at least two previous meta-analyses of single case research. It was applied with PAND in a meta-analysis of social skills interventions for children with autism (Schneider et al. 2008), and for academic interventions with students with behavior disorders (Vannest et al. 2010).

IRD is the difference or change in percent of high scores from baseline to intervention phase (Buckley and Newchok 2005; Thompson et al. 1998). For example, if baseline has 16% high scores, and the treatment phase has 83% high scores, IRD will be $.83 - .16 = .67$. A high score in the baseline is one which is above some B scores, and a low score in intervention phase is one which is below some phase A scores. If all phase B scores are above all phase A scores, IRD equals 1.00. If scores in A and B are both at the same level, IRD equals zero. On a sample of 364 published data series (Parker et al. 2009), Percentage of Non-overlapping Data (PND) and IRD values were compared (PND, IRD): 10th percentile: .00, .37; 25th percentile: .25, .48; 50th percentile: .67, .72; 75th percentile: .94, .90; 90th percentile: 1.0, 1.0. Thus, neither PND nor IRD were able to discriminate among the most successful interventions. IRD could discriminate among the least successful interventions, but PND could not.

The IRD has a maximum value of 1.00 (no data-overlap between phases), and a chance-level of .50, which means that half of the phase A scores are larger than half of the B scores, which would be chance level change between phases. If users so wish, the IRD can be easily converted to a 0–100 range, where zero indicates chance level ($2 * IRD_{old} - 100 = IRD_{new}$) (Parker et al. 2009). Parker et al. interpreted IRD scores by comparing IRD calculations to visual analysis of data for 166 single case data sets, suggesting the following guidelines: IRD of approximately .50 or lower indicates small or questionable effects, IRD scores between approximately .50 and .70 are considered moderate effects, and IRD scores of approximately .70 or .75 or higher are considered to be large or very large effects. See Parker et al. for more detailed directions and examples for calculating IRD.

IRD Calculations

IRD calculations and their 84% confidence intervals for each research question are specified in Table 2. A confidence interval (CI) is a necessity for effect sizes, especially with small N studies (Thompson 2002, 2007; Fidler and Thompson 2001; Fowler 1985). The CI describes the degree of precision of an obtained score (the IRD, in this case). For an obtained IRD of .71, and a 90% CI of $.62 << .71 \gg .80$, we can be 90% certain that the true IRD lies somewhere between .62 and .80.

The 84% CI has very useful properties. First, for judging the precision of an individual IRD, an 84% confidence limit is liberal enough to permit decision-making within a clinical setting (e.g., changing or intensifying treatments) when those decisions are not high-stakes. But more importantly, comparing two 84% CIs for interval overlap is equivalent to making an inference test of differences at $p = .05$ (Schenker and Gentleman 2001; Payton et al. 2003; Browne 1979; Goldstein and Healy 1995; Payton et al. 2000). Thus, visual tests of significance are possible by comparing the CIs of any IRD pair in Figure 2.

Inter-Observer Agreement (IOA) for Effect Size Calculations

All of the 24 included articles had multiple IRD phase comparisons. For example, several studies included multiple clients and targeted outcomes. This resulted in a total of 191 individual IRD calculations. One hundred twenty-two (64%) were independently calculated by two of the authors. IOA was calculated by dividing the number of agreements (111) by the total number of IRD calculations (122) and multiplying by 100, resulting in an overall IOA of 91%. Disagreements were discussed and recalculated until both authors agreed. Once a high rate of agreement was attained (over 90%), the remaining IRD calculations were made by one author. The few errors that existed were due to difficult to view crowded graphs, counting errors, and incorrect hand calculations. PND was calculated for each comparison as well. Twenty percent were independently calculated by two of the authors, resulting in an overall IOA of 97%

Results

Descriptive Summary of Studies Included in the Analyses

Participants

Overall, 58 individuals participated in the studies. Thirty-seven (64%) of the participants had a diagnosis or met diagnostic criteria for autistic disorder; four (7%) were diagnosed with PDD-NOS; seven (12%) were diagnosed with autism and other developmental disabilities (e.g., intellectual disability); four (7%) had diagnoses of PDD-NOS and developmental disabilities; and five (9%) had diagnoses of autism, developmental disabilities, and sensory impairments (e.g., hearing impairments). Regarding age, 27 (47%) of the participants were preschool-aged (up to age 5 years), 18 (31%) were elementary-aged (ages 6–10 years), 7 (12%) were secondary-school aged (ages

Table 2 Summary of effect size results for combined effects, targeted behavioral outcomes, and intervention types

		IRD	IRD CI
Combined		0.99	0.98–0.99
Targeted behavioral outcomes	Communication	0.99	0.99–0.99
	Social skills	0.90	0.84–0.95
	Academics (Spelling)	0.79	0.76–0.82
	Challenging behaviors	0.80	0.76–0.84
Intervention types	Picture exchange communication system	0.99	0.98–0.99
	Other picture-based AAC systems	0.61	0.57–0.64
	Speech-generating devices	0.99	0.99–1.00

11–15 years), and 6 (10%) were categorized as young adults or adults (over age 15 years).

Settings

The studies were conducted in various settings. Fifteen (63%) of the 24 studies were conducted in schools or school-like settings (e.g., clinics with classroom set-ups). Of those, 10 (42%) included treatment in self-contained special education classrooms; seven (29%) included treatment in separate, isolated rooms (e.g., therapy rooms, assessment suites); two (8%) included treatment within general education settings; and one (4%) was unspecific (e.g., classroom at participants' schools). Four (17%) studies were conducted in preschools for typically developing children. Seven (29%) were conducted in home settings. One (4%) study was conducted in a classroom within a hospital and one (4%) in the school library. Some of the studies included phases in multiple settings or participants within a single study were treated within different settings, thus, the percentages sum to greater than 100%.

Targeted Behavioral Outcomes

The dependent variables investigated in the studies included communication skills (e.g., making requests verbally, with pictures, or via an SGD; symbol comprehension; nonword vocalizations); social interaction skills (e.g., spontaneous social initiations); academics (the only academic skill assessed was spelling); and challenging behaviors (e.g., aggression). Twenty of the studies (83%) investigated the effects of intervention on communication skills, two studies (8%) investigated effects on social skills, two (8%) investigated impact on academics, and five studies (21%) investigated challenging behaviors. Many of the studies included data on multiple dependent variables, so the sum of the percentages is greater than 100%.

It was hypothesized that because AAC interventions target communication skills, the treatments overall would have generally high effects on these skills. Further, while AAC interventions may not primarily target social skills, because communication and social interaction are linked (e.g., Carr and Felce 2007), it was hypothesized that AAC interventions would have at least moderate effects on social skills as well. Challenging behaviors are often communicative in nature, thus, it was also hypothesized that for participants who engaged in challenging behaviors, AAC interventions may have some effect on challenging behaviors (Thompson et al. 1998). However, this would not be the case for every participant, some of whom engaged in challenging behaviors for functions other than communicating requests for preferred items or activities, which are the primary target behaviors of AAC interventions for individuals with ASD. For example, some participants may engage in challenging behaviors to escape interactions or for self-stimulation. Finally, individuals with ASD often have difficulties with academic tasks due to difficulties communicating, thus, it was hypothesized that AAC interventions may have moderate effects on academic skills.

Intervention Types

The interventions included three categories of aided AAC systems: (a) PECS, (b) picture-based systems other than PECS, and (c) SGDs. Nine of the included studies (38%) involved implementation of PECS (Frost and Bondy 1994, 2002). Seven of the studies (29%) involved use of other aided, picture-based AAC systems (PIC). That is, these involved pointing to or exchanging pictures, but did not involve the same structured instructional protocol and had varied instructional procedures that did not have instructional manuals. The other eight studies (33%) involved the use of various procedures to teach participants to use SGDs. As with the PIC studies, the SGD studies did not adhere to a single instructional manual or protocol.

It was hypothesized that each of these interventions would have large effects on overall targeted behaviors. However, because PECS includes an instructional manual and protocol (Frost and Bondy 2002) and the researchers and teachers who implemented PECS in the included studies typically had attended PECS training, it was anticipated that PECS would have larger effects than either of the other two intervention types, which were implemented following no single instructional protocol or instructional manual.

Overall Effects of AAC on Targeted Behavioral Outcomes

The first research question was the simplest, asking about overall average effects of AAC, despite variations in targeted outcomes. An average effect size was computed by meta-analysis software (Meta module in NCSS, Hintze 2010), by weighting individual IRD results by the inverse of their standard error (Wolf 1986). This is perhaps the most popular method of combining results in meta-analyses (Rosenberg et al. 2000; Rosenthal 1991). Standard error is SD/sqrt(N), so two elements drove the weighting: N and SD. IRD results were weighted most heavily when scores had low variability and data series were long. When multiple clients within one study received identical treatments (IVs) and were measured on identical outcomes (DVs), their results were combined within-study for a single result with greater precision (because of the larger number of data points). The IRD calculated for overall effects of AAC (IRD = 0.99) indicates large effects. Further, the 84% confidence interval is narrow, strengthening the argument that the use of AAC has positive effects on behaviors of individuals with ASD. Overall PND calculations ranged from 0% to 100%, with a median of 76%, indicating that aided AAC is an effective treatment (Scruggs and Mastropieri 1998).

Variation in Effects on the Targeted Client Outcomes

The IRD calculated for each broad behavioral category indicated large effects for all of the dependant variables (i.e., communication skills, social skills, academics, and challenging behaviors). However, the IRD for communication skills (0.99) is significantly higher than that for the other three variables, as demonstrated by the lack of overlap in the CIs for communication skills and each of the other variables. There is significant overlap in CIs for academics and challenging behaviors; however, social skills effects were significantly higher than those for academics, as demonstrated by the lack of overlap. Social skills effects appear to be higher than those for challenging behaviors, although there is a small amount of overlap between their CIs. Figure 1 illustrates the IRD and 84% CIs for targeted behaviors.

Variation in Effect Dependent on Type of AAC Implemented

IRD calculations for the use of PECS and for the use of SGDs indicate large effects (0.99 for each); however, IRD for other picture-based AAC (0.61) use indicates only moderate effects. Further, as indicated by the significant overlap between the CIs for PECS and SGDs, neither shows significantly higher effects than the other. However, there is no overlap between the CIs for both PECS and SGDs and the confidence interval for other picture-based AAC, thus indicating that PECS and SGD use resulted in significantly higher effects than other picture-based systems. Figure 2 illustrates the IRD and 84% CIs for each AAC intervention averaged and by individual study. There is significant variation across studies, particularly those studies in which other picture-based AAC interventions were implemented, contributing to the lower average IRD calculation for these types of interventions.

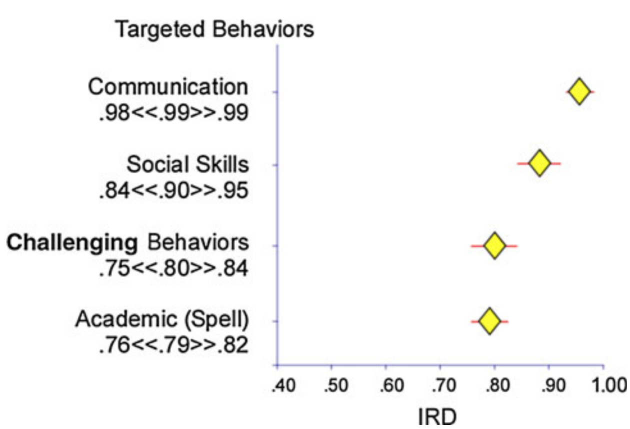

Fig. 1 IRD and 84% confidence intervals for targeted behaviors

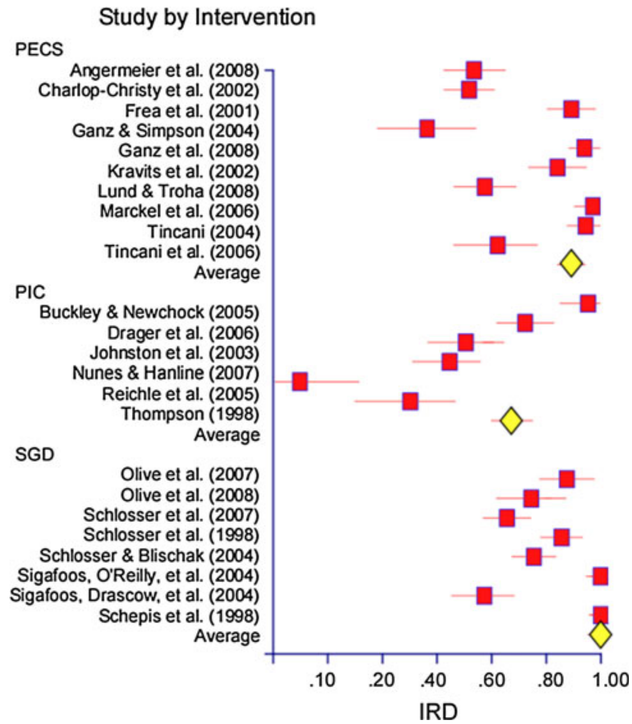

Fig. 2 IRD and 84% confidence intervals for AAC intervention type overall and by study

Discussion

Overall, this meta-analysis indicates strong effects for aided AAC on targeted behavioral outcomes in individuals with ASD. The participants in AAC studies had autism far more often than other diagnoses or combinations of diagnoses, including others on the autism spectrum (i.e., PDD-NOS), and those with ASD in combination with developmental disabilities, with or without sensory impairments. The limited numbers of participants with PDD-NOS may be due to the presence of less severe communication deficits in this population as compared to those individuals with autism. Smaller numbers of participants with multiple disabilities may be due to the low incidence of these disabilities, particularly sensory impairments diagnosed comorbidly with ASD.

As would be expected, the most common behavioral outcomes targeted by the studies were communication skills; however, several of the studies investigated the impacts of AAC on other behaviors including challenging behaviors, social skills, and academic skills. As illustrated in Fig. 1, the impact of AAC on communication skills appears to be greater than for other behavior categories; however, AAC seems to positively impact social skills, challenging behaviors, and spelling. Although the effects were not as strong as those for communication skills, it appears that improving communication may lead to improved social interaction and academics and decreased challenging behavior. It may be that because communication and social interaction are closely related, improvements in one results in related improvements in the other. Another explanation could be that AAC, though primarily targeting communication, also may address social interaction by teaching a social approach in order to communicate.

Further, when challenging behaviors function to communicate desire for an item or attention, or to escape an activity or attention, providing a more conventional means of communicating (e.g., simulated voice) may result in decreased challenging behaviors due to the efficiency of the new form of communication. For example, giving a picture to request candy may result in faster access to candy than a tantrum. Finally, improvements in academic skills may result from improved communication in individuals who might otherwise be able to perform such tasks if not for difficulty communicating knowledge.

Effect sizes calculated for social skills, academic skills (spelling), and challenging behaviors should be viewed with caution considering the small number of studies that investigated each of these variables. This points to the need for future research to investigate the effects of AAC on skills other than communication skills. Several more studies must be conducted before results may be meta-analyzed with confidence.

There was significant variation in IRD measures across studies, particularly for those involving implementation of other picture-based AAC strategies. The two studies with the lowest effect sizes (Reichle et al. 2005; Thompson et al. 1998) involved single participants, which contributed to wide CIs as well. Further, these studies included participants with both developmental delays and autism. Further, the studies with the lowest effect sizes within each AAC category included some of those with the oldest participants (Lund and Troha 2008; Reichle et al. 2005; Sigafoos et al. 2004). Older participants who have not previously learned basic communication skills may be more difficult to teach as they age.

Future research should investigate several questions. In particular, additional research is needed to thoroughly evaluate the effects of AAC interventions on social skills, challenging behaviors, and academic skills. The effects on academic skills have rarely been investigated. Research is needed that investigates instructional elements of AAC interventions that are most effective. There may be several aspects of AAC intervention types, particularly PECS and SGDs, that are particularly effective, such as the use of pictures versus written words or the implementation of a standardized treatment protocol. Research should investigate if different types of symbols have an impact on targeted behavioral objectives, whether participants within particular ASD categories respond better to AAC interventions, and whether the age during which intervention commences impacts its effectiveness. Research is also warranted to teach out the differential effects of different types of AAC systems and instructional variables, such as symbol iconicity, display layouts and organization, selection techniques, and instructional procedures.

There were some limitations to this meta-analysis. Although we included several variables, beyond communication skills, in this investigation, of course, the effects on these outcomes were considered only when the researchers collected data on those target outcomes. Many of the included studies only measured communication skills; thus, these studies or others may have found different effects on these variables if they had been analyzed and interpretation of effects on these outcomes variables is limited. This meta-analysis was limited to single case studies; therefore, by excluding group studies, the scope of this investigation is reduced in that it does not summarize all available evidence on the effects of AAC interventions. Further, the authors recognize that there is a publication bias in favor of publishing studies with positive results; thus, it is a limitation that this meta-analysis only included published works and excluded unpublished dissertations and theses. This meta-analysis is limited in that it only included research on aided AAC interventions for individuals with ASD; thus, it did not investigate the effects of unaided AAC, such as manual sign language, which has been successfully implemented with individuals with ASD (e.g., Tincani 2004). The participants included in the studies were primarily preschool and elementary-aged; thus, this analysis is limited in its applicability to older individuals. Finally, some researchers may consider the use of 84% confidence intervals to be too generous; small numbers ($N = 58$) in the study, the use of a new effect size measure, and wide confidence intervals requires readers to be cautious in interpreting the results of this analysis.

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