A Meta-Analysis of Single Case Research Studies on Aided Augmentative and Alternative

Communication Systems with Individuals with Autism Spectrum Disorders

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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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Delay in or lack of language development is a core characteristic associated with autism

spectrum disorders (ASD; American Psychiatric Association [APA], 2000). In fact, almost 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 augmentative and alternative communication (AAC) systems to

supplement existing speech or serve as the primary means for these students to communicate

(Mirenda, 2003). With the significant need for the use of AAC and the legal mandates of No

Child Left Behind (NCLB, 2001) and the Individuals with Disabilities Education Improvement

Act (IDEA, 2004) for educators to use evidence-based practices (EBP), questions arise regarding

what AAC systems are most effective with this population. While AAC is often implemented to

increase communication, questions remain regarding whether AAC also has effects on social

skills, challenging behaviors, and academics, thus strengthening their efficiency, by impacting

multiple skill domains concurrently.

AAC includes all forms of communication that allow individuals to communicate.

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 & Bondy, 1994, 2002). Because there is limited empirical evidence

supporting the use of sign language, many practitioners choose aided AAC systems for

individuals with ASD (Schuler, Prizant, & Wetherby, 1997) that require external equipment

(Bondy & Frost, 2002; Mirenda & Erickson, 2000). Aided, picture-based AAC systems are frequently implemented with individuals with ASD; such systems appear to match the characteristics of ASD (Mirenda & Erickson, 2000; Schuler & Baldwin, 1981). Fine motor difficulties are common in individuals with ASD, thus causing difficulty in learning manual signs (Hughes, 1996; Jones & Prior, 1985; Mirenda & Erickson, 2000; Seal & Bonvillian, 1997). However, picture-based systems are concrete and resemble their referents and appear to be well suited for individuals with ASD (Mirenda & Erickson, 2000; Rotholz, Berkowitz, and Burberry, 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 devices that usually combine digitized or synthesized speech with static visual symbols such as line drawings or photographs (Mirenda, 2003, Ogletree & Oren, 2006). While numerous AAC systems exist, some of the systems most widely used with children with autism include SGDs (e.g., Schlosser, Blischak, Belfiore, Bartley, & Barnett, 1998; Sigafoos, Drasgow, et al., 2004), PECS (Bondy & Frost, 2002; Frost & Bondy, 2002), and other picture-based systems (e.g., Frea, Arnold, & Vittimberga, 2001; Nunes & Hanline, 2007), thus, they are the focus of this article.

There has been a strong movement in the field to identify evidence-based practices (EBP) for individuals with autism (Reichow, Volkmar, & Cicchetti, 2008; Simpson, 2005, 2008; Simpson, McKee, Teeter, & Beytien, 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 and

colleagues (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, Cook, & Cook, 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.

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 & 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 & Therrien, 2008; Kavale, 1984, 1998, 2001; Parker, Hagan-Burke, & Vannest, 2007; Scruggs, 1992; Scruggs & Mastropieri, 1998; Scruggs, Mastropieri, & Casto, 1987) controversy exists regarding the type of metric to use (Scruggs, 1992; Scruggs & Mastropieri, 2001). Several single-participant research indices such as percent of non-overlapping data points (PND; Scruggs et al., 1987), percentage of all non-overlapping data (PAND; Parker et al., 2007) and the improvement rate difference (IRD, Parker, Vannest, & Brown, 2009) have been proposed. The percent of non-overlapping data (PND) metric determines the proportion of intervention data points that exceeds the highest value (when attempting to increase a behavior) or the lowest value (when attempting to decrease behavior) of the baseline data points (Scruggs & Mastropieri, 1998, 2001; Scruggs et al., 1987). The PND score is then used to determine the effectiveness of the treatment. Concerns regarding the use of PND as a single-case research statistical indices have been documented (Allison & Gorman, 1993; Scruggs & 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, Rusch, Kazdin, & Hartman, 1989).

Another index discussed in the literature 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 ES 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 improvement rate difference (IRD) is another index for calculating ES. This statistic summarizes the difference in "successful performance between baseline and intervention phases" (Parker et al., 2009, p. 135). 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). In addition, IRD has a well documented record of use (as risk difference) in medical research (Parker et al., 2009). 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, Goldstein, & Parker, 2008), and for academic interventions with students with behavior disorders (Vannest, Harrison, Parker, Harvey, & Ramsey, in press).

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, Cook, & Cook, 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, Kamps, Kemmerer, & Potucek, 2002), challenging behaviors (e.g., Frea, Arnold, & Vittimberga, 2001), 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 & 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 & 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)?

<div align="center">Method</div>

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 six 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, 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 & Stone, 2006a; 2006b), 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 & 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., ABCD designs). 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, Stoner, Bock, & Parton, 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 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, Carr, Halle, McGee, Odom, and Wolery's (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 inter-observer 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), and single-case designs demonstrating experimental control.

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). Although the dependent variables

measured were all socially valid and important skills, many of the included studies did not

measure social validity.

[table 1 about here]

Measurement of Effect Sizes

Line graphs pertaining to AAC use were analyzed to determine a "magnitude of change

index," or "effect size," called the Improvement Rate Difference (IRD; Parker, Vannest, &

Brown, 2009), between baseline and intervention phases (including return to baseline and

treatment in the two studies with reversal designs; Buckley & Newchok, 2005; Thompson, et al.,

1998), excluding generalization and maintenance data points. The application of IRD to single

case research is quite new (Schneider, Goldstein & Parker, 2008). IRD is modeled after the "risk

difference" from medical research (Armitage, Berry & Matthews, 2002; Altman, 1999; Sackett,

Richardson, Rosenberg & Haynes, 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 is the difference or change in percent of high scores from baseline to intervention

phase. 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, Vannest, & Brown, 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.

PND is the longest lived and most published measure of effect in single-case research (Marquis et al., 2000; Parker et al., 2009; Scruggs & Mastropieri, 1998). Despite its popularity, its major disadvantages include lack of a known sampling distribution, so p-values and confidence intervals are not available (Parker et al., 2009). Yet for short data series, confidence intervals are essential to reflect the credibility of an obtained effect. That shortcoming, plus the concern that PND attends to only a single data point in phase A, has spurred the development of more defensible non-overlap indices, one of which is IRD. 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.

Inter-observer Agreement 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%

<div align="center">Results</div>

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 to

10 years), 7 (12%) were secondary-school aged (ages 11 to 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; non-word 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 & 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 & 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

& 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.

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 & 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>>.80, we can be 90% certain that the true IRD lies somewhere between 62% and 80%.

[table 2 about here]

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 & Gentleman, 2001; Payton, Greenstone & Schenker, 2003; Browne, 1979; Goldstein & Healy, 1995; Payton, Miller & Raun, 2000). Thus, visual tests of significance are possible by comparing the CIs of any IRD pair in Figure 2.

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, 2007), 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, Adams, & Gurevitch, 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 & 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.

<p align="center">[figure 1 about here]</p>

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.

[figure 2 about here]

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 Figure 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.

Effect sizes calculated for the independent variables can be viewed with more confidence because seven or more studies investigated each of the types of aided AAC included in this meta-analysis. Effect sizes for both PECS and SGD were large, although the effect size calculated for other picture-based AAC was significantly lower. One reason for the higher effects may be that there is an established protocol for PECS so it is usually implemented as intended in research. Although few of the PECS studies reported treatment integrity, the researchers reported implementing PECS according to the instructional manual (Frost & Bondy, 1994, 2002). Only two of the other picture-based AAC studies reported treatment integrity and they typically do not follow a standardized protocol, although they may have similarities to PECS. The SGD interventions also do not follow a standard protocol, however, two aspects set them apart from the PECS and other picture-based AAC studies. All but one of the SGD studies reported treatment integrity and there was significant overlap in authorship of the SGD studies. Five authors (e.g., Blischak, Olive, O'Reilly, Schlosser, and Sigafoos) co-authored multiple studies, suggesting highly similar intervention procedures. These aspects indicate that the procedures used to implement AAC may be more important than the particular AAC system used. The results of this meta-analysis should be viewed with some caution in regard to drawing conclusions about superiority of one system over another because the studies measured similar dependent variables in different ways across studies, and each category of targeted behavioral outcome included various specific. Some of the included studies investigated single skills within a category while others investigated several skills within a single or multiple categories.

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. In fact, many of the studies with lower IRD scores within each intervention category included participants with co-morbid diagnoses, suggesting that AAC interventions may be less effective with students with multiple disabilities. Further, the studies with the lowest effect sizes within each AAC category included some of those with the oldest participants (Lund & Troha, 2008; Reichle et al.; Sigafoos, Drascow, 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. Finally, 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.

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. Finally, 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).

References

References marked with an asterisk indicate studies included in the meta-analysis.

Allison, D.B., & Gorman, B.S. (1993). Calculating effect sizes for meta-analysis: The case of the single case. *Behaviour Research & Therapy, 31*, 621-631.

Altman, D. G. (1999). *Practical statistics for medical research*. Bristol, UK: Chapman & Hall.

American Psychiatric Association [APA]. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

American Speech-Language-Hearing Association [ASHA]. (1997). *Augmentative and Alternative Communication (AAC)*. Retrieved from http://www.asha.org/public/speech/disorders/AAC.htm.

*Angermeier, K., Schlosser, R. W., Luiselli, J. K., Harrington, C., & Carter, B. (2008). Effects of iconicity on requesting with the Picture Exchange Communication System in children with autism spectrum disorder. *Research in Autism Spectrum Disorders, 2*, 430-446.

Armitage, P., Berry, G., & Matthews, J. N. S. (2002). *Statistical methods in medical research* (4th ed.). Malden, Massachusetts: Blackwell Science.

Banda, D.R. & Therrien, W.J. (2008). A teacher's guide to meta-analysis. *Teaching Exceptional Children, 41*, 66-71.

Beck, A. R., Stoner, J. B., Bock, S., & Parton, T. (2008). Comparison of PECS and the use of a VOCA: A replication. *Education and Training in Developmental Disabilities, 43*, 198-216.

Beretvas, S. N., & Chung, H. (2008). A review of single-subject design meta-analyses: Methodological issues and practice. *Evidence-Based Communication Assessment and Intervention, 2*, 129-141.

Bondy, A.S. & Frost, L.A. (1994). The Picture Exchange Communication System. *Focus on*

       Autistic Behavior, 9, 1-19.

Bondy, A. & Frost, L. A. (2002). *A pictures worth: PECS and other visual communication*

       strategies in autism. Bethesda, MD: Woodbine House.

Browne, R. H. (1979). On visual assessment of the significance of a mean difference. *Biometrics*,

       35, 657-665.

*Buckley, S. D., & Newchok, D. K. (2005). Differential impact of response effort within a

       response chain on use of mands in a student with autism. *Research in Developmental*

       Disabilities, 26, 77-85.

Carr, D., & Felce, J. (2007). Brief report: The effects of PECS teaching to phase III on the

       communicative interactions between children with autism and their teachers. *Journal of*

       Autism and Developmental Disorders, 37, 724–737.

Centers for Disease Control and Prevention (CDC). (2007). Prevalence of —autism spectrum

       disorders—Autism and Developmental Disabilities Monitoring Network, 14 Sites, United

       States, 2002. MMWR SS 2007; 56(No.SS-1). Retrieved August 28, 2009, from

       http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5601a2.htm.

*Charlop-Christy, M. H., Carpenter, M., Le, L., LeBlanc, L. A., & Kellet, K. (2002). Using the

       picture exchange communication system (PECS) with children with autism: Assessment

       of PECS acquisition, speech, social-communication behavior, and problem behavior.

       Journal of Applied Behavior Analysis, 35, 213-231.

Cochrane Collaboration. (2006). Retrieved May 18, 2006, from http://www.cochrane.org/.

*Drager, K. D. R., Postal, V. J., Carrolus, L., Castellano, M., Gagliano, C., & Glynn, J. (2006).

       The effect of aided language modeling on symbol comprehension and production in two

preschoolers with autism. *American Journal of Speech-Language Pathology, 15*, 112-125.

Fidler, F., & Thompson, B. (2001). Computing correct confidence intervals for ANOVA fixed- and random-effects effect sizes. *Educational and Psychological Measurement*, *61*, 575-604.

Fowler, R. J. (1985). Point estimates and confidence intervals in measures of association. *Psychological Bulletin*, *98*, 160-165.

*Frea, W. D., Arnold, C. L., & Vittimberga, G. L. (2001). A demonstration of the effects of augmentative communication on the extreme aggressive behavior of a child with autism within an integrated preschool setting. *Journal of Positive Behavior Interventions, 3*, 194-198.

Frost, L., & Bondy, A. (1994). *The Picture Exchange Communication System training manual*. Cherry Hill, NJ: Pyramid Educational Consultants, Inc.

Frost, L., & Bondy, A. (2002). *The Picture Exchange Communication System training manual* (2nd ed.). Cherry Hill, NJ: Pyramid Educational Consultants.

Ganz, J.B., Parker, R., & Benson, J. (2009). The impact of the Picture Exchange Communication System: Effects on communication and collateral effects on maladaptive behaviors. *Augmentative and Alternative Communication, 25*, 250-261.

Ganz, J. B., Sigafoos, J., Simpson, R. L., & Cook, K. E. (2008). Generalization of a pictorial alternative communication system across instructors and distance. *Augmentative and Alternative Communication, 24*, 89-99.

*Ganz, J. B., & Simpson, R. L. (2004). Effects on communicative requesting and speech

　　　　development of the picture exchange communication system in children with

　　　　characteristics of autism. *Journal of Autism and Developmental Disorders, 34*, 395-409.

*Ganz, J. B., Simpson, R. L., & Corbin-Newsome, J. (2008). The impact of the Picture Exchange

　　　　Communication System on requesting and speech development in preschoolers with

　　　　autism spectrum disorders and similar characteristics. *Research in Autism Spectrum*

　　　　Disorders, 2, 157-169.

Glass, G.V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher,*

　　　　5, 3-8.

Goldstein, H., & Healy, M. J. R. (1995). The graphical presentation of a collection of means.

　　　　Journal of the Royal Statistical Society, *158*, 175-177.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005). The use of

　　　　single-subject research to identify evidence-based practice in special education.

　　　　Exceptional Children, 71, 165-179.

Individuals with Disabilities Education Improvement Act Regulations, 34 C.F.R. § 300.35 *et seq.*

*Johnston, S., Nelson, C., Evans, J., & Palazolo, K. (2003). The use of visual supports in

　　　　teaching young children with autism spectrum disorder to intiate interactions.

　　　　Augmentative and Alternative Communication, 19, 86-103.

Kavale, K.A. (1984). Potential advantages of the meta-analysis technique for research in special

　　　　education. *Journal of Special Education*, *18*, 61-72.

Kavale, K.A. (1998). Some methods are more effective than others. *Intervention in School and*

　　　　Clinic, 33, 195-200.

Kavale, K.A. (2001). Meta-analysis: A primer. *Exceptionality, 9*, 177-183.

*Kravits, T. R., Kamps, D. M., Kemmerer, K., & Potucek, J. (2002). Brief report: Increasing

communication skills for an elementary-aged student with autism using the Picture

Exchange Communication System. *Journal of Autism and Developmental Disorders, 32*,

225-230.

*Lund, S. K., & Troha, J. M. (2008). Teaching young people who are blind and have autism to

make requests using a variation on the Picture Exchange Communication System with

tactile symbols: A preliminary investigation. *Journal of Autism and Developmental*

Disorders, 38, 719-730.

*Marckel, J. M., Need, N. A., & Ferreri, S. J. (2006). A preliminary analysis of teaching

improvisation with the Picture Exchange Communication System to children with autism.

Journal of Applied Behavior Analysis, 39, 109-115.

Marquis, J. G., Horner, R. H., Carr, E. G., Turnbull, A. P., Thompson, M., Behrens, G. A.,

Magito-McLaughlin, D., McAtee, M.L., Smith, C.E., Anderson-Ryan, K., & Doolabh, A.

(2000). A meta-analysis of positive behavior support. In R. Gersten, E. Schiller, S.

Vaughn, & J. Schumm (Eds.), *Contemporary special education research: Syntheses of*

knowledge base on critical instructional issues (pp. 137-178). Mahwah, NJ: Lawrence

Erlbaum.

Scruggs, T. E., & Mastropieri, M. A. (1998). Summarizing single-subject research: Issues and

applications. *Behavior Modification, 22*, 221-242.

Mirenda, P. (2003). Towards functional augmentative and alternative communication for

students with autism: Manual signs, graphic symbols, and voice output communication

aids. *Language, Speech, and Hearing Services in Schools, 34*, 203-216.

No Child Left Behind Act of 2001, 20 U.S.C. 70 §6301 *et seq.* (2002)

*Nunes, D., & Hanline, M. F. (2007). Enhancing the alternative and augmentative

    communication use of a child with autism through a parent implemented naturalistic

    intervention. *International Journal of Disability, Development and Education, 54*, 177-

    197.

Ogletree, B.T. & Oren, T. (2006). *How to use augmentative and alternative communication*.

    Austin, TX: Pro-Ed.

*Olive, M. L., Cruz, B. d. l., Davis, T. N., Chan, J. M., Lang, R. B., O'Reilly, M. F., et al.

    (2007). The effects of enhanced milieu teaching and a voice output communication aid on

    the requesting of three children with autism. *Journal of Autism and Developmental*

    Disorders, 37, 1505-1513.

*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. *Research in Autism Spectrum Disorders, 2*, 223-236.

Parker, R. I., Hagan-Burke, S. & Vannest, K. (2007). Percentage of all non-overlapping data

    (PAND): An alternative to PND. *The Journal of Special Education, 40*, 194-204.

Parker, R. I., Vannest, K. J., & Brown, L. (2009). The Improvement Rate Difference for single

    case research. *Exceptional Children, 75*, 135-150.

Payton, M. E., Greenstone, M. H., & Schenker, N. (2003). Overlapping confidence intervals or

    standard error intervals: What do they mean in terms of statistical significance? *Journal*

    of Insect Science, 3(34), 1-6.

Payton, M. E., Miller, A. E., & Raun, W.R. (2000). Testing statistical hypotheses using standard

    error bars and confidence intervals. *Communications in Soil Science and Plant Analysis*,

    31, 547-552.

*Reichle, J., McComas, J., Dahl, N., Solberg, G., Pierce, S., & Smith, D. (2005). Teaching an
individual with severe intellectual delay to request assistance conditionally. *Educational
Psychology, 25*, 275-286.

Reichow, B., Volkmar, F.R. & Cicchetti, D.V. (2008). Development of the evaluative methods
for evaluating and determining evidence-based practices in autism. *Journal of Autism
and Developmental Disorders, 38*, 1311-1319. doi: 10.1007/s10803-007-0517-7

Rosenberg, M. S., Adams, D. C. & Gurevitch, J. (2000). MetaWin 2.0. [Computer software]
Sunderland, MA: Sinauer Associates.

Rosenthal, R. (1991). *Meta-analysis procedures for social science research*. Beverly Hills, CA:
Sage.

Sackett, D. L., Richardson, W. S., Rosenberg, W., & Haynes, R. B. (Eds.). (1997). *Evidence-
based medicine: How to practice and teach EBM*. London: Churchill Livingstone.

Schenker, N., & Gentleman, J. F. (2001). On judging the significance of differences by
examining overlap between confidence intervals. *The American Statistician*, *55*, 182-186.

*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. *Journal of Applied Behavior Analysis, 31*,
561-578.

*Schlosser, R. W., & Blischak, D. M. (2004). Effects of speech and print feedback on spelling by
children with autism. *Journal of Speech, Language and Hearing Research, 47*, 848-862.

*Schlosser, R. W., Blischak, D. M., Belfiore, P. J., Bartley, C., & Barnett, N. (1998). Effects of
synthetic speech output and orthographic feedback on spelling in a student with autism:
A preliminary study. *Journal of Autism and Developmental Disorders, 28*, 309-319.

Schlosser, R.W. & Sigafoos, J. (2009). Navigating evidence-based information sources in

augmentative and alternative communication. *Augmentative and Alternative*

Communication, 25, 225-235.

*Schlosser, R. W., Sigafoos, J., Luiselli, J. K., Angermeier, K., Harasymowyz, U., Schooley, K.,

et al. (2007). Effects of synthetic speech output on requesting and natural speech

production in children with autism: A preliminary study. *Research in Autism Spectrum*

Disorders, 1, 139-163.

Schneider, N., Goldstein, H., & Parker, R. (2008). Social skills interventions for children with

autism: A meta-analytic application of percentage of all non-overlapping data (PAND).

Evidence-Based Communication Assessment and Intervention, *2*, 152–162.

Scruggs, T.E. (1992). Single subject methodology in the study of learning and behavioral

disorders: Design, analysis and synthesis. In T.E. Scruggs & M.A. Mastropieri (Eds.),

Advances in learning and behavioral disabilities (Vol. 7, pp. 223-248). Greenwich,

CT:JAI Press.

Scruggs, T.E. & Mastropieri, M.A. (1998). Summarizing single-subject research: Issues and

applications. *Behavior Modification, 221*, 221-242.

Scruggs, T.E. & Mastropieri, M.A. & Casto, G. (1987). The quantitative synthesis of single-

subject research: Methodology and validation. *Remedial and Special Education, 8*(2),

24-33.

*Sigafoos, J., Drasgow, E., Halle, J. W., O'Reilly, M., Seely-York, S., Edrisinha, C., et al.

(2004). Teaching VOCA use as a communicative repair strategy. *Journal of Autism and*

Developmental Disorders, 34, 411-422.

*Sigafoos, J., O'Reilly, M., Seely-York, S., & Edrisinha, C. (2004). Teaching students with developmental disabilities to locate their AAC device. *Research in Developmental Disabilities, 25*, 371-383.

Simpson, R. L. (2005). Evidence-based practices and students with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities, 20*, 140-149.

Simpson, R.L. (2008). Children and youth with autism spectrum disorders: The search for effective methods. *Focus on Exceptional Children, 40*, 1-14.

Simpson, R.L., McKee, M., Teeter, D., Beytien, A. (2007). Evidence-based methods for children and youth with autism spectrum disorders: Stakeholder issues and perspectives. *Exceptionality, 15*, 203-217.

Tankersley, M., Cook, B.G., & Cook, L. (2008). A preliminary examination to identify the presence of quality indicators in single-subject research. *Education and Treatment of Children, 31*, 523-548.

Thompson, B. (2002). What future quantitative social science research could look like: Confidence intervals for effect sizes. *Educational Researcher, 31*, 24-31.

Thompson, B. (2007). Effect sizes, confidence intervals, and confidence intervals for effect sizes. *Psychology in the Schools, 44*, 423-432.

*Thompson, R. H., Fisher, W. W., Piazza, C. C., & Kuhn, D. E. (1998). The evaluation and treatment of aggression maintained by attention and automatic reinforcement. *Journal of Applied Behavior Analysis, 31*, 103-116.

*Tincani, M. (2004). Comparing the Picture Exchange Communication System and sign language training for children with autism. *Focus on Autism and Other Developmental Disabilities, 19*, 152-163.

*Tincani, M., Crozier, S., & Alazetta, L. (2006). The Picture Exchange Communication System:

  Effects on manding and speech development for school-aged children with autism.

  Education and Training in Developmental Disabilities, 41, 177-184.

Vannest, K. J. Harrison, J., Parker, R., & Harvey, K. T, Ramsey, L. (in-press). Improvement

  Rate Differences of academic interventions for students with emotional and behavioral

  disorders. *Remedial and Special Education.*

White, D. M., Rusch, F. R., Kazdin, A. E., & Hartman, D. P. (1989). Applications of meta-

  analysis in individual subject research. *Behavioral Assessment, 11*, 281-296.

Wolf, F. M. (1986). *Meta-analysis: Quantitative methods for research synthesis*. Beverly Hills,

  CA: Sage.

Yoder, P., & Stone, W. L. (2006a). A randomized comparison of the effect of two prelinguistic

  communication interventions on the acquisition of spoken communication in

  preschoolers with ASD. *Journal of Speech. Language, and Hearing Research, 49*(4),

  698-711.

Yoder, P., & Stone, W. L. (2006b). Randomized comparison of two communication

  interventions for preschoolers with autism spectrum disorders. *Journal of Counseling and

  Clinical Psychology, 74*(3), 426-435.

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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 to 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 (-.20 - .89)
Buckley and Newchock (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 to 12 years; AUT	Therapy rooms; classrooms; home	PECS	Child-led, Nauturalistic, teacher led	Frequency and percentage of intervals of social-	All participants mastered all PECS phases. Social	32 phase change comparisons

						communication skills and challenging behaviors	communication increased while challenging behaviors decreased.	IRD Range: (-.10 - .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 to 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, Simpson et al. (2008)	Multiple baseline across participants	Two boys and one girl; ages 3 to 5 years; AUT, DD	Homes	PECS	Child led	Percentage of independent picture exchanges and word approximations,	Two out of the three participants reached mastery. The final	6 Phase change comparisons IRD Range: (.84 - .98)

						average number of intelligible words per trial	participant showed little progress.	
Johnston et al. (2003)	Multiple probe across participants	Three boys; ages 4 to 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)
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 to 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	Two boys; ages 4 and 5	Home	PECS	Child led	Frequency of independent	Number of improvised	6 Phase change

	across descriptors	years; AUT				requests with adjective improvisation	requests improved. Skills generalized across items, settings and people.	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: (-.13 – 1.0)
Olive et al. (2007)	Multiple probe	Three boys; ages 3 to 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	Challenging behaviors decreased and use of VOCA increased.	8 Phase change comparisons IRD Range: (.29 – 1.0)

							incorrect pronoun use	
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: (-.56 - .20)
Schepis et al. (1998)	Multiple probe across participants and time	Three boys and one girl; ages 3 to 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
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: (-.12 – 1.0)
Schlosser et al. (2007)	Alternating treatment	Five boys; ages 8 to 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	6 Phase change comparisons IRD Range: (.80 - .89)

								elicited vocalizations.	
Schlosser and Blischak (2004)	Adapted alternating treatment	Four boys; ages 8 to 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: (0.0 – 1.0)
Sigafoos, Drascow, 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, O'Reilly, et al. (2004)	Delayed multiple baseline across participants	Two boys and one girl; ages 12 to 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: -.15 & .64
Tincani (2004)	Alternating treatment	One boy and one girl; ages 5 and 6 years;	Classroom (self-contained)	PECS	Child Led	Percentage of picture requests and	One participant responded more strongly	8 Phase change comparisons

							vocalizations	to PECS while the other responded more positively to sign language. Vocalization increased for both participants.	IRD Range: (.73 – 1.0)
		AUT, DD, PDD							
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: (-.64 – 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.	

Note: 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.

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

Figure Captions

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

Figure 2. IRD and 84% confidence intervals for AAC intervention type overall and by study.
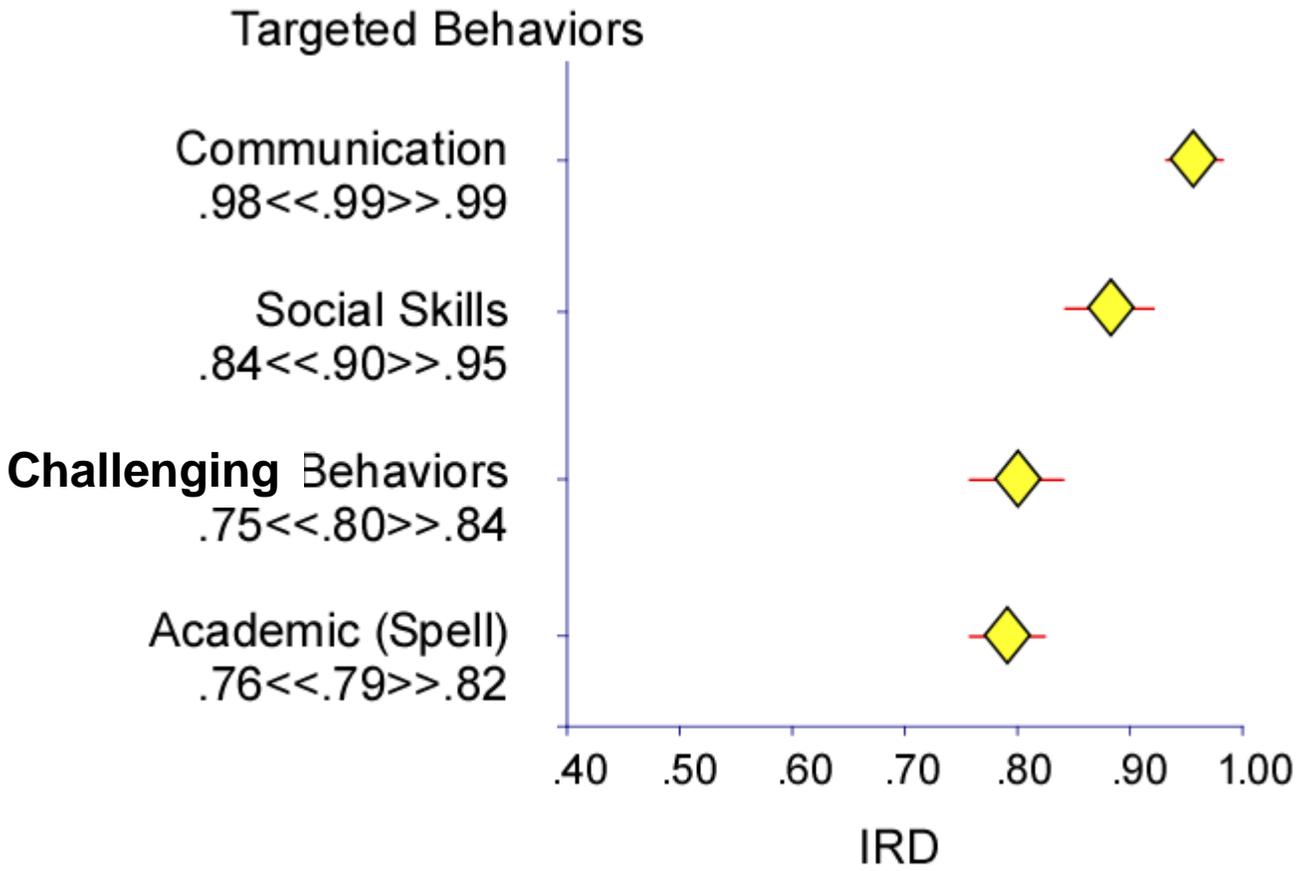
Figure 1 Top

Figure 2 Top

Figure 2 Top